

Customer Engineering  
Manual of Instruction

Tektronix Oscilloscopes

**MAJOR REVISION, August 1960**

This edition, Form 223-6725-2, obsoletes Form 223-6725-1 and all earlier editions. Significant changes have been made throughout the manual, and this new edition should be reviewed in its entirety.

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# Tektronix Oscilloscopes

This manual presents the fundamentals of cathode ray oscilloscopes and specific operating information for seven instruments manufactured by Tektronix Incorporated. The Tektronix oscilloscopes presented are those models currently supplied as IBM office tools.

The cathode ray oscilloscope is a prime maintenance tool for modern data processing equipment. Because of complex high-speed circuitry, it is necessary to make dynamic checks of the operating circuits. The oscilloscope fulfills this need by displaying voltage changes with respect to time. The display is generated by moving a single point of light on the face of a cathode ray tube (CRT). At high speeds, the moving point appears as a line of light, referred to as the oscilloscope trace (Figure 1).

## Basic Oscilloscope

The basic cathode ray oscilloscope consists of four sections: a cathode ray tube, a vertical amplifier, a horizontal amplifier, and a time base generator (Figure 2). The basic function of a section is the same in all instruments. However, internal circuitry varies, depending on the type of work for which the oscilloscope is intended.

### Cathode Ray Tube

An essential part of the oscilloscope is the cathode ray tube (CRT). The pattern of the voltage under test is observed on the face of this tube. Major components

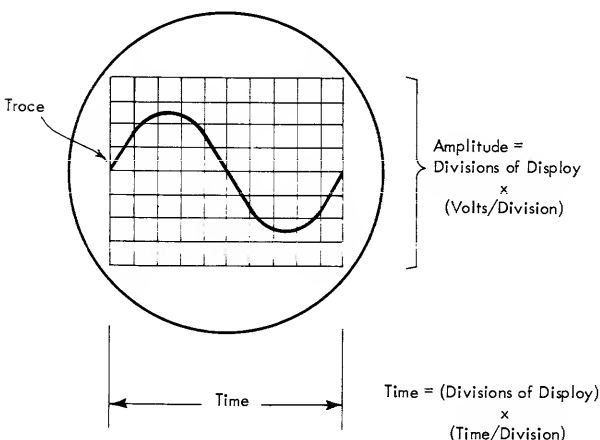


Figure 1. Oscilloscope Display

of the CRT are: a glass envelope, an electron gun, deflection plates, and a fluorescent screen (Figure 3).

**Electron Gun.** The electron gun is located at the small end of the glass envelope. The gun generates a concentrated beam of electrons and directs the beam toward the viewing screen. The electron gun consists of a heater, a cathode, a control grid, a focusing anode, and accelerating anodes. The cathode is constructed of a material that emits electrons freely when heated by the heater (filament). The control grid regulates the amount of electrons in the beam, and therefore controls the intensity (brilliance) of the point of light. The focusing anode narrows the beam, and the accelerating anodes speed up the beam to a high velocity.

**Deflection Plates.** The horizontal deflection plates move the electron beam along the X-axis of the CRT screen, and the vertical plates move the beam along the Y-axis. The electron beam may be positioned to any

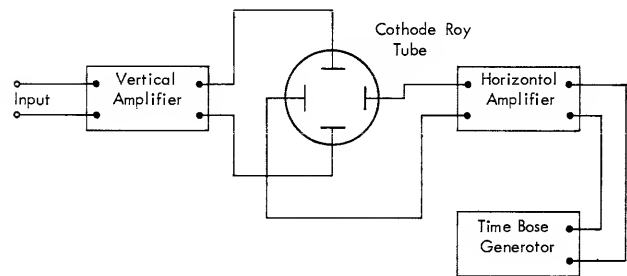


Figure 2. Basic Oscilloscope

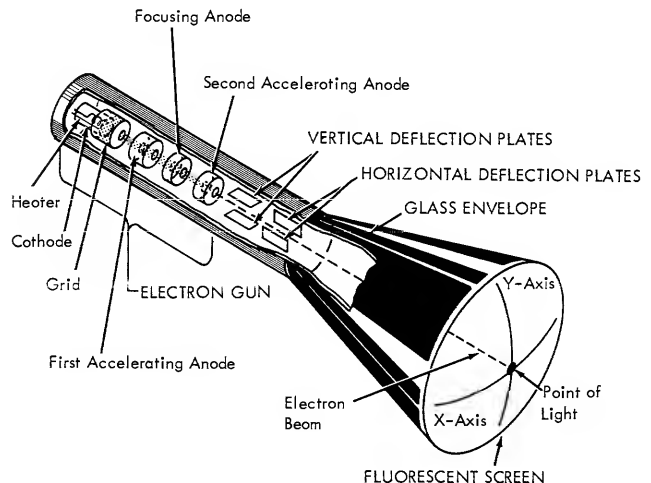


Figure 3. Cathode Ray Tube

point on the screen by applying the proper voltage to these plates.

**Fluorescent Screen.** This screen is a phosphor coating on the inside face of the glass envelope. When the electron beam strikes this coating, a point of light is produced. The fluorescent screen continues to glow after the electron beam is removed. The length of the afterglow (persistence) depends on the type of phosphor coating used. The most desirable persistence of the screen depends upon the oscilloscope application.

### *Vertical Amplifier*

The vertical amplifier improves the sensitivity of the vertical deflection plates. The CRT deflection plates alone are insensitive, requiring as much as 100 volts difference in potential to move the electron beam one inch. The vertical amplifier amplifies (or attenuates) the input waveform so that its amplitude will be correct for the vertical deflection plates. The vertical section is often subdivided into a preamplifier and a main amplifier. In this case, the main amplifier gain is fixed, and the preamplifier gain is variable. The vertical section becomes more complex as its frequency range is extended.

### *Horizontal Amplifier*

The horizontal amplifier, in effect, increases the sensitivity of the CRT horizontal deflection plates in the same manner as the vertical amplifier increases the sensitivity of the vertical deflection plates. The horizontal amplifier is simpler in design because its requirements are not as stringent. It is required only to amplify the output from the time base generator, which has a constant amplitude output.

### *Time Base Generator*

To plot voltage against time, it is necessary to move the point of light at a constant speed in one direction. This is usually done by using a linear voltage change to move the point horizontally (X-axis). Because speed and distance are known, the horizontal divisions may be read as units of time.

The linear voltage change (sweep) is the time base for the display, and is formed by the time base generator. The output of this circuit is a sawtooth waveform that is then applied to the horizontal amplifier. Oscilloscope time base generators operate over a wide range of speeds. The proper speed is selected by front panel controls. Several other controls are used to specify the desired starting point of the time base. Starting the time base (triggering) is done to synchronize the time base generator with the input waveform. This synchronization is necessary to insure that the

point of light will follow the exact same path on the face of the CRT for many sweeps. A great number of sweeps are usually necessary to allow the operator to examine the display.

## **Oscilloscope Measurements**

As previously mentioned, the oscilloscope gives a visual display of voltage plotted against time. In this display the operator may determine the period of the input waveform, the over-all shape of the waveform, the amplitude at any point of the waveform, and various time relations within the waveform and between the waveform and the time base.

### *Frequency Measurements*

To perform a useful function, a changing waveform repeats itself in a cyclic fashion. The time between the beginning of one cycle and the beginning of the next is called the period. From an oscilloscope display, because the time scale is calibrated in units of time. If the time between cycles is known, the waveform frequency is determined by the formula:  $F = 1/T$ . A particular oscilloscope is capable of measuring only those frequencies within a specified range. As the frequency is broadened, the instrument becomes more complex and, therefore, more costly.

### *Waveshape*

Complex waveforms may contain many components. These parts may represent various signals or various logical functions performed by the circuit. The oscilloscope display allows the operator to determine if a portion of the waveform is missing, distorted, or if unwanted components are in the waveform. Machine reference manuals often contain pictures of waveshapes taken at key points. The waveshape may then be compared with the reference to determine the location of a failing component.

### *Amplitude*

Each component of a complex waveform has its own limits as well as time duration limits. Unless the proper criteria are met, the waveform will not properly represent the logical function. The amplitude, in volts, is measured on the vertical (Y-axis) scale of an oscilloscope. Each vertical division represents a specific voltage of voltage, determined by control settings. The total voltage is determined by the number of divisions

from a reference line, multiplied by the volts each division represents (Figure 1).

### *Time Relations*

The time of a particular occurrence within a machine is usually critical with respect to one or more other events. The oscilloscope is often used to determine the elapsed time between two events. In some cases, the parts of a single waveform comprise the two events. The distance between the two points is then counted as a number of horizontal divisions. Each division represents a specific increment of time determined by control settings. The actual time is found by multiplying the number of divisions by the time each division represents (Figure 1).

The time relation between two separate waveforms is often needed. A simple way to measure this relation is to trigger the time base with one waveform, while displaying the second waveform. The time between the two waveshape points may now be read from the start of the sweep to the second point. Some oscilloscopes have provisions for displaying two waveforms at the same time. In this manner the entire waveforms may be compared. Other special features for time relation measurements are discussed in the Special Features and Controls Section.

## **Operating Functions**

Many controls and jacks appear on the front panel of the oscilloscope. To obtain a useful display, each control must be set to a specific position. The controls are usually divided into four groups: CRT controls, vertical controls, triggering controls, and horizontal controls.

### *CRT Controls*

The CRT controls allow the operator to obtain a well-defined trace of the desired intensity. The operator should not allow a high intensity spot or trace to remain on the CRT. A high intensity beam damages the phosphor viewing screen.

### *Vertical Controls*

The operator must set vertical controls to convert the amplitude of his signal to that required by the CRT vertical deflection plates. This is done by selecting an amount of voltage to be represented by each vertical scale division. For example, if the input signal changes 8 volts, a good vertical scale is 2 volts per division. This scale gives a waveform four divisions high on the viewing screen.

The operator must also determine a reference point for the sweep. For example, if the waveform goes only positive from its reference, the oscilloscope reference should be near the bottom of the vertical scale. If both positive and negative excursions are expected, the reference should be in the center. Whenever the reference for the input waveform is other than zero, the operator may change the reference to zero by removing the DC component of the waveform.

### *Triggering Controls*

The triggering controls allow the operator to choose the precise starting point of the sweep. To accomplish this, the operator must first choose a trigger source. The source may be the input signal, some external waveform, or the AC power line. After the source is selected, the operator chooses a portion of the selected waveform for triggering. The proper setting of the triggering controls allows the time base to be started at any desired point.

### *Horizontal Controls*

In the horizontal section, the operator first chooses a time base generator. This choice is usually limited to the generator within the oscilloscope and some external time base generator. Some oscilloscopes, however, are equipped with two time base generators. The remaining selections within the horizontal section concern the sweep speed. As the sweep speed is reduced, more cycles of a particular waveform are seen on the viewing screen. The operator may view as much or as little of a waveform as he desires, within the limits of the instrument.

### *Operating Rules*

1. Never allow a high intensity display for a prolonged period of time. A high intensity beam can destroy the phosphor coating on the CRT face.
2. Use extreme caution if the instrument covers are removed. Lethal voltages are plentiful inside an oscilloscope.
3. If the covers are removed, be especially careful when working near the ventilating fan blades. The fan blades are not well protected.
4. Keep the air filter unobstructed to prevent overheating of the instrument.
5. Avoid dropping the plastic probes. They are easily broken.
6. Select a triggering source that is equal to, or slower than, the input waveform. A stable trace cannot be obtained if the triggering frequency is too high.

## Oscilloscope Features and Controls

This section gives general oscilloscope information applicable to any instrument. The control names and the examples given are taken from several models of Tektronix oscilloscopes.

Figure 4 shows the major blocks of a typical oscilloscope. The remainder of this section is devoted to the controls and features of each block.

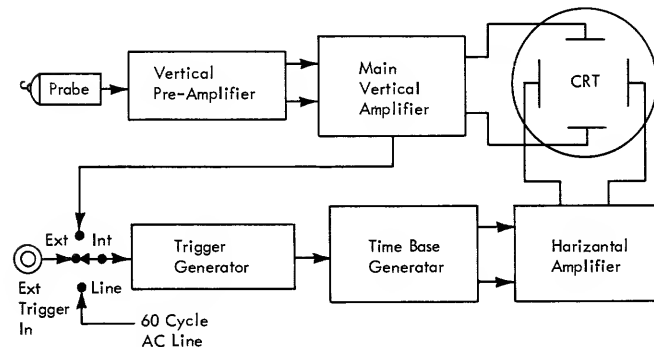


Figure 4. Typical Oscilloscope

### Test Probe Assembly

Oscilloscope test probes are used to couple the waveform under test into the instrument. The simplest type of coupling is an ordinary piece of wire. This coupling, however, has limited application. The oscilloscope is designed to operate over a wide range of frequencies and amplitudes; the coupling to the oscilloscope must be equally versatile. Two important qualities of a good oscilloscope test probe are:

1. Low distortion of the waveform
2. High input impedance

#### Construction

The test probe assembly (Figure 5), commonly called the probe, consists of four major parts: a connector; a length of coaxial cable; a probe, or head; and a probe tip.

The connector and coaxial cable transfer the signal from the head to the oscilloscope preamplifier. Coaxial cable is used to prevent picking up unwanted signals.

Three types of probe heads are used: non-attenuating, attenuating, and cathode follower.

Non-attenuating probes are seldom used because their input impedance is lower than that of other types. They are useful when checking very low level signals, where circuit loading is not critical.

Attenuating probes are the most widely used because they offer a high impedance and faithfully reproduce the input signal. They are simple, reliable. The most common attenuating factor for probes is  $\times 10$ . Figure 5 illustrates an attenuating probe assembly.

Cathode follower probes offer the highest input impedance. This type of probe contains a cathode follower circuit inside the probe head. Cathode follower probes are more fragile than the other type and require an additional cable to carry power to the cathode follower.

All Tektronix probes have replaceable screw-on tips. The tip provides the physical and electrical connection with the point of test. Common probe tips are:

1. Insulated retractile tip
2. Hook shank tip
3. Alligator clip assembly
4. Pin jack tip
5. Straight shank tip

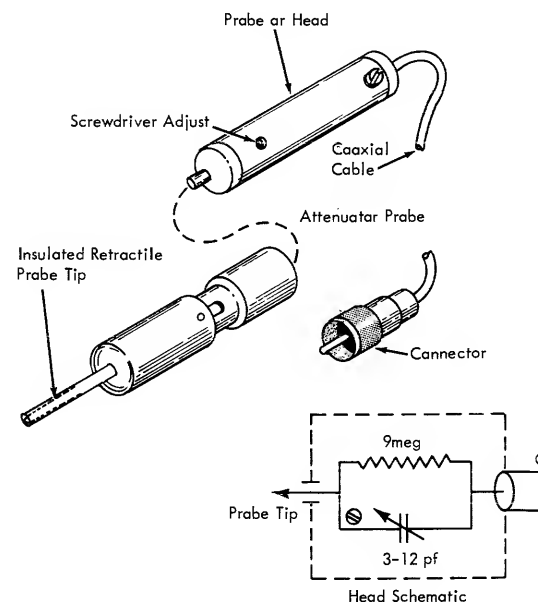


Figure 5. Test Probe Assembly



The insulated retractile tip, the hook shank tip, and the alligator clip assembly are designed to free the operator from holding the probe. The pin jack tip is used when working with machines that have pin jack test terminals. The straight shank tip is used when working with terminals that are very close to each other.

## Compensation

The variable capacitor in the probe head (Figure 5) is adjusted to balance the input grid capacity. This adjustment is called probe compensation. Compensation is performed by applying a square wave to the probe and adjusting for square-topped waves on the viewing screen (Figure 6). Probe compensation should be checked each day, before using the oscilloscope; after changing probes; and after the probe receives a shock (such as being dropped).

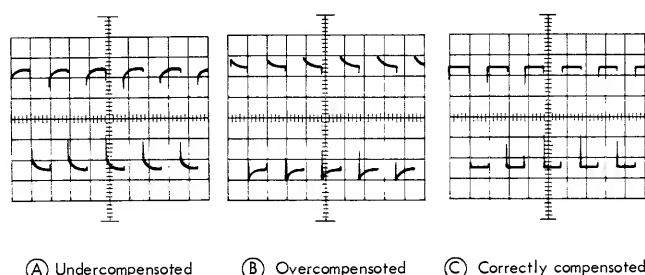


Figure 6. Probe Compensation

## Preamplifier

The preamplifier is the link between the probe and the main vertical amplifier. The Tektronix main vertical amplifiers have a fixed gain that provides one division of deflection with .1 volt input. The preamplifier must convert the oscilloscope input signal to a compatible amplitude.

The preamplifier is housed in a plug-in unit in all Tektronix instruments except the portable models. The circuit configuration varies with the type of plug-in unit.

Front panel controls associated with the preamplifier are an AC/DC switch, a volts/div switch and a variable attenuator control. Figure 7 illustrates a typical preamplifier.

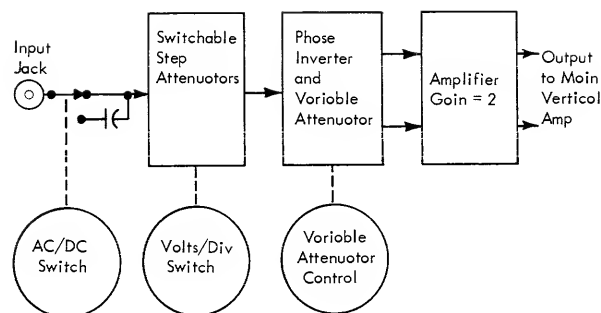


Figure 7. Typical Preamplifier

## Input Switching

Input switching in the preamplifier is accomplished by the AC/DC switch and the volts/div switch.

The circuits of the vertical section of Tektronix oscilloscopes are directly coupled, and therefore indicate a DC potential. Thus, these oscilloscopes may be used as a vacuum tube voltmeter (VTVM), provided the AC/DC switch is in the DC position. With the switch in the AC position, the DC component is removed by inserting a capacitor in series with the input. The AC position is used whenever it is desired to observe small changes that are occurring on a large reference voltage. An example of this is observing the ripple on a power supply voltage.

The volts/div switch is used to establish the value of the vertical scale divisions, and therefore determines the height of the displayed waveform. A typical volts/div switch has the following positions: .05, .1, .2, .5, 1, 2, 5, 10, and 20. The following example illustrates the function of this switch: An input waveform of 2 volts is being observed; if the volts/div switch setting is .5 (non-attenuating probe), the waveform is four divisions high on the viewing screen.

The volts/div switch operates by switching the input through various combinations of step attenuators, and in some cases, an amplifier. For example, if the volts/div switch setting is 2, the input waveform is directed through a  $\times 10$  attenuator and a  $\times 4$  attenuator, producing an effective attenuation of  $\times 40$ . The waveform is then fed to an amplifier with a fixed gain of 2, meaning that the over-all attenuation of the preamplifier is  $\times 20$ . If a 2-volt signal is now applied to the input, it will be attenuated to .1 volt. As previously mentioned, .1 volt into the main vertical amplifier causes one division of deflection. Figure 8 illustrates a step attenuator typical of those used in Tektronix preamplifiers.

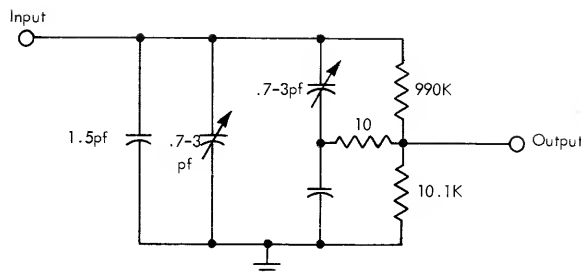


Figure 8. Typical Attenuator ( $\times 100$ )

From the preceding example .05 volt appears to be the smallest amplitude that can cause one division of vertical deflection (no attenuators used). Some preamplifiers, however, use a switchable amplifier with the step attenuators. A typical amplifier used in this manner has a gain of ten, meaning that the range of the preamplifier is extended to .005 volt/div.

### Variable Attenuator

The variable attenuator is used to obtain values of attenuation between the steps provided by the volts/div switch. This control is not calibrated and must be set fully clockwise whenever an amplitude measurement is made. The volts/div switch positions are correct only when the variable control is fully clockwise.

The variable attenuator control is located in the cathode circuit of the inverter stage (Figure 9). The control operates by changing the cathode resistance of

V1 and V2, thereby affecting the gain of the circuit. V2 is a grounded grid amplifier, receiving signals from V1. Circuit components are chosen to amplify signals from the plates of V1 and V2. Because V1 is an inverter and V2 is not, their outputs are of opposite phase.

### Screwdriver Adjustments

Most Tektronix preamplifiers have two screwdriver adjustments: gain and DC balance. Figure 9 shows the arrangement of these potentiometers within the circuit.

The gain adjustment is used to set accurate preamplifier gain to correspond to the volts/div switch positions. Adjust the control as follows:

1. Apply a calibrating voltage of .2 volt peak to the oscilloscope input (see note).
2. Set the volts/div switch to .05.
3. Be sure the variable attenuator control is set fully clockwise.
4. Rotate the gain adjustment control until the displayed waveform is exactly four divisions high.

NOTE: Tektronix oscilloscopes have a built-in voltage calibrator that provides the waveform for adjustment.

The DC balance control sets the bias of V1 and V2 (Figure 9) to allow the variable attenuator control to provide equal gain of V1 and V2 in an identical manner. The DC balance adjustment is made while rotating the variable attenuator control back and forth. The correct balance is found when the trace position is no longer shifted by rotation of the variable attenuator control.

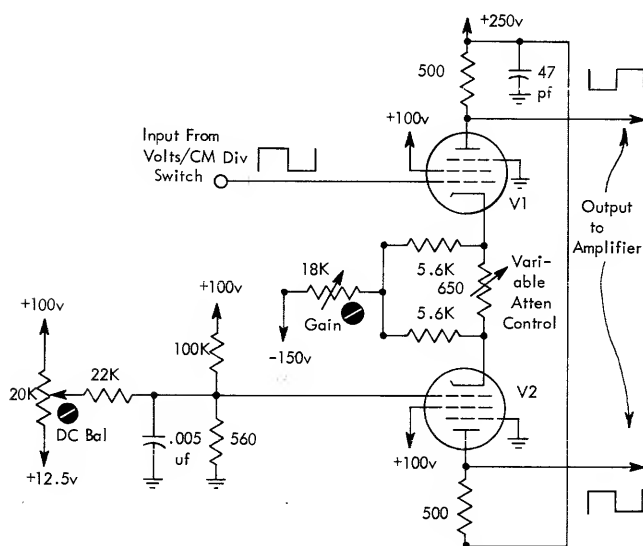


Figure 9. Phase Inverter and Variable Attenuator

### Vertical Amplifier

The oscilloscope vertical amplifier should provide gain over a wide range of frequencies, serving the original waveshape. All Tektronix amplifiers have a gain that provides one division of deflection with a .1-volt input. The frequency response, however, varies from model to model. Only the vertical amplifier control is available to the operator. The vertical position control allows the operator to move the trace up or down on the viewing screen.

### Push-Pull Circuitry

The oscilloscope input waveform is passed through an inverter circuit in the preamplifiers. The inverter produces two equal signals that are 180 degrees out of phase with respect to each other. From the inverter to the CRT, the signals are

separated. Finally, each signal is routed to one of the two CRT vertical deflection plates. This method of signal handling is referred to as push-pull operation and is used for four reasons:

1. CRT distortion is reduced when the deflection plates are fed in push-pull.
2. Lower power supply voltages may be used, since any one tube need provide only half of the required amplitude.
3. Tubes with lower power handling capabilities may be used.
4. Power supply regulation is less critical because variations tend to cancel out.

### *Distributed Amplifiers*

To obtain a wider bandpass, some Tektronix main vertical amplifiers employ a distributed amplifier as their output section. A distributed amplifier has parallel amplifier stages, each stage most efficient over a different range of frequencies.

Tektronix distributed amplifiers consist of six parallel, push-pull stages (Figure 10). Each push-pull stage is tuned to a different frequency range. The frequency response of the distributed amplifier (dc to 30 megacycles) is the combination of all six stages (Figure 10).

### *Balanced Delay Line*

Except for portable models, Tektronix oscilloscopes contain a balanced delay line that delays the input signal. The delay line is located between the main vertical amplifier and the CRT vertical deflection plates. The vertical signal is delayed to allow time for starting

the sweep. Oscilloscopes having the delay network can display the entire waveform that triggered the sweep. The network consists of approximately 50 adjustable delay sections (capacitor-coil combinations) that give a total delay of .2 microsecond.

### *Indicator and Pick-off Circuits*

For the operator's convenience, most Tektronix oscilloscopes have neon beam indicators. When the trace is not visible, the indicators indicate the location of the beam. Two neon indicators are associated with the vertical amplifier—up and down. If the up neon is lighted, the beam is beyond the top of the viewing screen. If the beam is positioned too low to be seen, the down indicator is lighted. Two other beam indicators, left and right, are associated with the horizontal amplifier.

Although the input waveform is used primarily for vertical deflection, it is also made available to other circuits by means of the vertical amplifier pick-off circuit. The pick-off circuit feeds the trigger generator if the operator has chosen the input waveform as the trigger source (Figure 4). In most oscilloscopes, the pick-off circuit also feeds a front panel jack—vertical signal out.

### *Vertical Position Control*

The vertical position control allows the operator to shift the trace up or down. This is accomplished by dual potentiometers, each working with half of a push-pull vertical amplifier stage. The control operates by applying a more positive bias to one tube, while applying a more negative bias to the other tube. Thus, the result is a change of the dc reference on vertical deflection plates. For example, if the vertical position control is turned clockwise, the trace shifts upward on the CRT face. This is due to a positive shift in the channel feeding the up deflection plate, and a negative shift in the channel feeding the down deflection plate. Because the up deflection plate has gone more positive, the negative electron beam is attracted upward toward this plate. The down deflection plate aids in upward beam movement by exerting less attraction for the beam, because the plate is shifted in a negative direction.

Logically, the vertical position control is part of the main vertical amplifier; however, it is sometimes physically located in the preamplifier circuitry. Operation of the control is the same, regardless of its physical location.

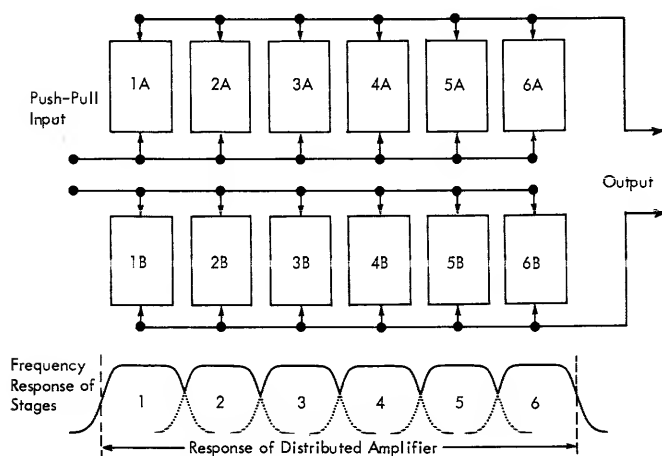


Figure 10. Distributed Amplifier

## Cathode Ray Tube

The oscilloscope is built around the CRT. Other oscilloscope sections exist only to provide the CRT with the voltages necessary for generating a display. The advantage of a CRT is that it converts an electron beam to a source of light. The electron beam has extremely low inertia, and therefore can be moved almost instantaneously.

Cathode ray tubes are classified by size, type of deflection and focusing, and type of viewing screen.

The size of a CRT is given in inches, indicating the diameter of the viewing screen. Tektronix model numbers give the size of the CRT used in the instrument. For example, a 300 series oscilloscope such as the 310A contains a three-inch CRT. The model 535 contains a five-inch CRT.

The type of deflection and focusing employed is either magnetic or electrostatic. These names indicate the kind of field that acts upon the electron beam for deflection and focusing. Some CRT's use a combination of the methods, such as magnetic deflection and electrostatic focusing. Tektronix oscilloscope CRT's employ electrostatic deflection and focusing exclusively.

Viewing screens are classified by the type of phosphor coating used. The phosphor coating may emit light of any one of several colors. Varying amounts of persistency are available with each color. Tektronix normally supplies a P1 or a P2 viewing screen, although other phosphors are optional. The P1 screen gives a green fluorescence of medium persistence, and is noted for its high efficiency. The P2 phosphor provides a medium persistence screen and gives a blue-green fluorescence with a yellow-green after-glow. Tektronix three-inch CRT's are supplied with P1 phosphor, and five-inch CRT's are supplied with P2 phosphor.

### *CRT Operation*

The CRT operates by generating a high velocity beam of electrons that bombard a phosphor viewing screen. Functional elements of the CRT operate in a high vacuum atmosphere inside a glass envelope. The electron beam is generated and largely controlled by the electron gun assembly. Once the beam is out of the gun, the only control remaining is the deflection plates. Without deflection plates, the beam would always strike the center of the viewing screen. The deflection plates, however, bend the beam in accordance with the potential supplied to them by the vertical and horizontal amplifiers. In this manner, the beam may be directed to any point on the viewing screen.

To accelerate the electron beam to the required velocity, strong electrostatic fields are necessary. For

this reason, high voltages are applied to the accelerating potential of a CRT is measured the cathode and the viewing screen. This is generally between 1000 and 10,000 volts, depending on the size of the CRT. The Tektronix five-inch, for example, use an accelerating potential of 10,000 volts.

The source of electrons for the beam is the cathode. The cathode is made of a material that freely emits electrons whenever it is heated. A resistance heater, raises the temperature of the cathode to a necessary point.

Electrons are drawn away from the cathode by accelerating anodes that are highly positive with respect to the cathode. Between the cathode and the first anodes, however, is a fine mesh called the control grid. The control grid acts as a valve to control the amount of electrons allowed to leave the cathode. During normal operation, the control grid is biased negative to repel electrons until a sweep is requested. The negative bias is removed when a sweep comes into the oscilloscope in the form of a trigger. The trigger, in turn, causes a positive voltage to be applied to the control grid, thereby turning on or unblanking the electron beam.

Before leaving the gun assembly, the beam passes through a shaped electrostatic field, which causes the beam to converge, or focus, at the viewing screen. The action of the shaped electrostatic field on the beam is similar to the action of a lens on a light beam. The shaped electrostatic field is produced by focus and astigmatism elements.

### *Electron Gun Controls*

The only oscilloscope controls directly associated with the CRT are the electron gun controls. These include intensity control, the focus control, and the astigmatism control.

The intensity control sets the bias of the control grid. Normally, this control is set to keep the beam cut off until a sweep is generated. The control grid receives a positive, constant-amplitude, unblanking voltage whenever the sweep is triggered. This unblanking voltage adds to the bias voltage to unblank the CRT. The intensity control must be set higher for faster sweep speeds or for lower sweep repetition rates to avoid damaging the viewing screen, do not set intensity higher than necessary.

The focus and astigmatism controls together produce a sharply defined trace. Some oscilloscopes have a focus control; in this case, the focus control is adjusted for the smallest possible point. The astigmatism control affects the shape of the beam. Although

focus and astigmatism controls interact, their optimum settings may be found quickly by following two rules:

1. Adjust focus for a small point only.
2. Adjust astigmatism for a round point only.

Because of interaction between the two controls, their adjustment should be repeated until very little change of either is necessary.

## Trigger Generator

The trigger generator starts, or triggers, the sweep generator. The sweep generator requires a specific triggering waveform. The purpose of the trigger generator, therefore, is to accept a wide variety of signals and convert them to the required triggering waveform. The trigger generator is composed of a trigger amplifier stage and a trigger shaper stage.

### Triggering Sources

The operator may choose any one of three triggering sources: external, internal, or line.

When external is selected, a front panel jack is connected to the input of the trigger generator, allowing the operator to connect any desired signal to the trigger generator.

If internal is selected as the trigger source, the vertical amplifier pick-off circuit is connected to the trigger generator, allowing the operator to trigger with the input waveform without using an additional cable.

The line selection causes the trigger generator to be fed with the power line frequency (usually 60 cycles per second).

### Triggering Modes

Five triggering modes are used by Tektronix: DC, AC slow, AC fast, AC automatic, and high frequency sync. All oscilloscopes do not employ all five modes of triggering.

**DC Mode.** The DC triggering mode allows a voltage change, no matter how slow, to trigger the sweep generator. A voltage change as low as .2 volt can be used for triggering in this mode.

**AC Slow Mode.** This mode, sometimes called AC, is similar to the DC mode; however, a capacitor is inserted in the trigger line to prevent slow changes from triggering the sweep. Signals below approximately 20 cycles per second will not trigger the sweep in this mode.

**AC Fast Mode.** A resistor capacitor filter is inserted in the trigger line in the AC fast, or low frequency

reject, mode. Waveforms below approximately 2 kilocycles will not trigger the sweep in this mode. AC fast is especially useful in preventing low frequency noise (such as 60 cycles per second) from triggering the sweep.

**AC Automatic Mode.** The AC automatic (AC auto) mode of triggering is useful with frequencies of 60 cycles per second to 2 megacycles. In this mode, the trigger shaper stage is converted to a multivibrator that free-runs at about 50 cycles per second. Repetitive triggers applied to the shaper cause it to lock-in and run at their frequency. The output of the shaper is used to trigger the sweep. Extremely low amplitude signals may be used in this mode. AC auto has the advantage of always displaying a sweep, even without a trigger input. Because of this, the oscilloscope may be used to measure DC voltages as well as a wide variety of AC signals without readjustment of the triggering controls.

**High Frequency Sync Mode.** This mode (HF sync) causes the trigger to bypass the trigger generator and go directly to the sweep generator. Although high amplitude triggers (2 volts) are required, this mode is useful for frequencies above 5 megacycles.

### Triggering Controls

Three front panel controls are associated with the trigger generator: trigger slope, triggering mode, and triggering level.

**Trigger Slope Switch.** This switch selects the trigger source—external, internal, or line. However, the switch includes two positions for each source (six-position switch). The two positions for a source are plus and minus, thus allowing the operator to choose either the rising or falling portion (slope) of the trigger waveform. For example, if the trigger slope switch is set to plus internal, the sweep will be triggered on the positive-going portion of the input signal.

**Triggering Mode Switch.** This switch allows the operator to select a mode of triggering. Effective triggering frequencies for each mode are:

DC	DC to 5mc
AC slow	20cps to 5mc
AC fast	2kc to 5mc
AC auto	60cps to 2mc
HF sync	5mc to 30mc

**Triggering Level Control.** This control selects the amplitude at which triggering will occur. For low amplitude signals, the control must be set near zero. The zero position is at the midpoint of the control travel. As the triggering level control is moved clockwise away from its midpoint, triggering occurs during the posi-

tive portion of the waveform at increasing amplitudes. To trigger during the negative portion of the waveform, the control must be moved counter-clockwise from its midpoint. Figure 11 illustrates the point of triggering for settings of the trigger slope and triggering level controls. The triggering level control is inoperative when either AC auto or high frequency sync modes of triggering are selected.

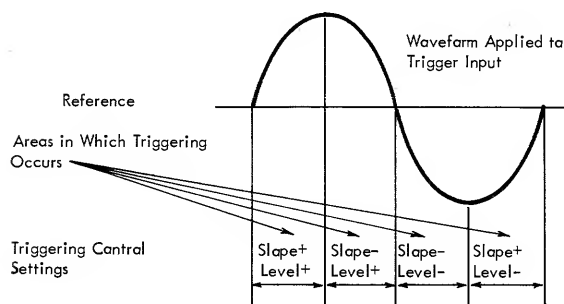


Figure 11. Effects of Trigger Slope and Triggering Level Controls

## Time Base Generator

The time base generator originates the linear voltage change that is applied to the CRT horizontal deflection plates. For a specific sweep speed, the beam must always move the same distance in a given period of time, and the controls must accurately indicate this speed to the operator.

Tektronix time base generators consist of three circuits: a multivibrator, a sweep generator, and a hold-off circuit. These three circuits have two outputs: a linear sawtooth waveform to feed the horizontal amplifier, and a positive level shift to unblank the CRT (Figure 12).

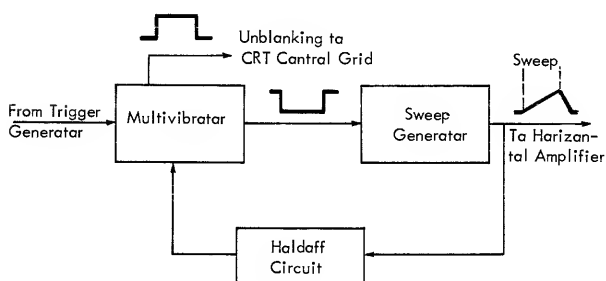


Figure 12. Time Base Generator

## Circuit Operation

The time base generator is normally inoperative until a trigger is received from the trigger generator. When a trigger is received, the trigger generator switches the multivibrator, generating two outputs. One multivibrator output is a positive level shift that unblanks the CRT. The other output is a negative level shift that turns on the sweep generator (Figure 12).

The sweep generator output is a linear rise that continues to rise until the multivibrator returns to its static condition. The output of the sweep generator is fed to the horizontal amplifier, which moves the electron beam across the face of the CRT. The sweep generator output is also fed to the hold-off circuit.

The hold-off circuit performs two functions: it prevents the multivibrator from reverting to its static condition until the electron beam reaches the right-most edge of the viewing screen, and it prevents triggers from retriggering the multivibrator until sufficient time has elapsed for the circuit capacitors to restore.

When the hold-off circuit switches the multivibrator back to its static condition, two functions are performed. The unblanking voltage returns to its static state, thereby blanking the CRT. The other multivibrator output shifts upward, stopping the sweep generator and returning its output to the static state. The electron beam moves rapidly to the left as the sweep generator is restored. This right-to-left movement of the electron beam is called retrace. The hold-off circuit continues to provide an output to the multivibrator, holding it in its static state. After a time delay, the hold-off circuit output drops to its original state, and the time base generator is now ready to accept a new trigger, which will start a new cycle.

The multivibrator is a bistable circuit, receiving a negative signal to switch from the static state to the active state and a positive signal to revert to the static state. The trigger generator provides the negative input to the multivibrator, and the hold-off circuit provides the positive input.

The sweep generator is a modified Miller integrator circuit called a Miller run-up circuit. It operates by feeding an out-of-phase output back to its input through a sweep timing capacitor. In this arrangement the output can rise only as fast as the sweep timing capacitor charges. The charge time of the timing capacitor depends on the size of the capacitor and the value of the resistor that is in series with the capacitor.

The hold-off circuit is a pair of cathode followers that receive the sawtooth sweep waveform and convert it to a triangular shaped wave. The positive peak of the waveform switches the multivibrator to its static state.

state and holds it in this condition for a period of time determined by the trailing edge of the waveform. The hold-off circuit does not allow a sweep repetition rate greater than 250 kilocycles.

### *Controls and Indicators*

One control, stability, is associated with the multivibrator. This control, which sets the bias of the multivibrator, has three settings: free-running, disabled, and synced.

The free-running position is obtained by turning the stability control completely clockwise. This allows the multivibrator to free-run, giving continuous sweeps without an input. Triggers received from the trigger generator are ignored with this stability control setting. The free-running position is used when setting the vertical positioning control for a reference trace. It is also used when measuring DC voltages.

The disabled position of the stability control is the counter-clockwise extreme. In this position, the multivibrator is held in its static state and cannot be triggered. This position is used when operating some oscilloscopes that have dual time base generators. See the Wide-Band Oscilloscopes With Sweep Delay Section for the specific application.

The synced position of the stability control is the position normally used. With the control in this position, the multivibrator is switched by triggers from the trigger generator. For this reason, this position is sometimes called the triggered position of the control. To locate the synced position:

1. Turn both stability and triggering level controls completely clockwise. A free-running sweep will be displayed.
2. Rotate the stability control counter-clockwise a few degrees past the point where the trace disappears. The triggering level control may now be adjusted for the desired level of triggering.

These two steps will always locate the synced position of the stability control, and may be used with or without an input to the oscilloscope.

For the operator's convenience, some Tektronix oscilloscopes have a preset position of the stability control. The preset position is obtained by extreme counter-clockwise rotation, which switches another stability potentiometer into the circuit, replacing the main stability control. The preset stability potentiometer is screwdriver-adjusted to the synced, or triggered, setting. This allows the operator to switch to a synced stability setting, instead of locating the setting with the main stability control.

The stability control is used in all modes of triggering except AC auto.

Three controls and an indicator may be associated with the sweep generator: time/div, multiplier, variable time/div, and a neon indicating an uncalibrated condition. All these controls are not found on any one instrument.

The time/div switch is used to switch different size timing capacitors into the sweep generator circuit, thereby changing the sweep speed. If the time/div switch is in the five-microsecond position, the electron beam will move across the viewing screen at the rate of five microseconds per division. Because the viewing screen is ten divisions wide, the time for a complete sweep is five microseconds  $\times$  ten divisions, or 50 microseconds. The operator must check the position of this switch in order to make time measurements with the oscilloscope. Two other controls, however, that can modify the basic time/div setting are the multiplier control and the variable time/div control.

The multiplier control changes sweep speed by switching in resistors, through which the timing capacitor must charge. If the oscilloscope has a multiplier control, the position of the control must be multiplied by the time/div setting to obtain the sweep speed. In the preceding example, if the multiplier position is ten, sweep speed is 50 microseconds per division instead of five microseconds per division. The total time for one sweep is now 500 microseconds.

The variable time/div control is a potentiometer also in series with the sweep timing capacitor. The variable control allows the operator to obtain sweep speeds that are between the steps provided by the time/div switch. The variable control is uncalibrated and must be in its extreme clockwise position whenever time measurements are made. The extreme clockwise position of this control is marked CALIBRATED and indicates that time/div switch positions are now correct. As a warning to the operator, a neon indicator lamp is lit if the variable time/div control is not in the calibrated position.

The hold-off circuit has one control that may be located either on the front panel or elsewhere. This is the sweep length control, which varies the length of the trace from approximately four divisions to ten divisions. The control operates by varying the sawtooth amplitude fed into the hold-off circuit, thereby determining the sawtooth amplitude at which the multivibrator is turned off. Although the sweep is normally ten divisions long, greater intensity may be obtained by decreasing the sweep length. Because the sweep requires less time, more sweeps can occur in a given period of time.

## Horizontal Amplifier

The horizontal amplifier is the link between the time base generator and the CRT horizontal deflection plates. This amplifier is often called the sweep amplifier because it normally amplifies the output of the sweep generator.

### *Input Control*

The input to the horizontal amplifier is selected by the horizontal input (horizontal display) switch. For oscilloscopes with one time base generator, this control selects either the output of the sweep generator or a front panel jack (horizontal input). The horizontal display switch of an oscilloscope with dual time base generators has positions for selecting either sweep generator as well as the horizontal input jack.

All Tektronix oscilloscopes have attenuators associated with the horizontal input jack. These attenuators provide horizontal gain control whenever an external sweep is used. Both step and variable attenuators are used for this function.

### *Horizontal Positioning*

A horizontal position control is provided to shift the trace horizontally across the viewing screen. This control allows the operator to adjust the trace so that it

starts precisely at the left-most edge of the markings. This condition must be met whenever measurements are made in reference to the start of the sweep. The control operates by shifting the phase of the input sweep signal. In addition to normal horizontal position control, some oscilloscopes also have a vernier for this adjustment.

Two horizontal beam position indicators, one on the left, are provided for the operator's convenience. These indicators, with the vertical beam position indicator, locate the position of the beam whenever it is on the viewing screen.

### *Magnifier*

A 5× magnifier switch allows the operator to selectively multiply any normal sweep speed by a factor of five. The switch removes degenerative feedback from the horizontal amplifier, increasing the sweep length from 10 divisions to 50 divisions. Because total sweep time is not changed, 10 divisions of horizontal scale now require 1/5 the normal time. If the normal horizontal division is 50 microseconds, the magnified sweep speed will be 50 divided by 5, or 10 microseconds/division. The operator may select any 10-division portion of the magnified sweep with the horizontal position control.

On some oscilloscopes, a neon indicator is provided whenever the 5× magnifier is on to warn the operator that the time/div switch settings do not reflect true sweep speed.



## Special Features and Controls

This section describes special features incorporated in some Tektronix oscilloscopes, and features not related to the block diagram of the preceding section. The controls and applications for these features are also included. Special features discussed are: illuminated graticule, voltage calibrator, Z-input, plug-in units, single sweep, and sweep delay.

### Illuminated Graticule

The viewing screen divisions are etched on a transparent plastic plate (graticule). The graticule, together with a colored light filter, is mounted directly in front of the CRT face. The light filter improves the contrast of the CRT presentation in normal room lighting.

#### *Scale Illumination*

The graticule is illuminated by two lamps at the top edge of the graticule. The scale illumination control changes the brilliance of these lamps. Some scale illumination controls are marked with F-stop settings. These markings are used in photographing CRT displays.

#### *Graticule Markings*

The graticule for 300 series instruments provides quarter-inch divisions, subdivided into five parts. The 500 series graticules have one-centimeter divisions also subdivided into five parts.

Graticule markings appear either red or white, depending on the graticule mounting. The color of the markings is changed by rotating the graticule one-half turn (180 degrees).

### Voltage Calibrator

The voltage calibrator is a square wave generator circuit independent of other oscilloscope circuits. Its output is a positive square wave of approximately 1000 cycles, available only at a front panel jack.

#### *Calibrator Controls*

Although the square wave frequency may vary as much as 30 percent, the amplitude is closely calibrated. Any

one of eleven to eighteen peak-to-peak amplitudes is made available by using one or two selector switches, labeled calibrator, amplitude calibrator, or square wave calibrator.

The calibrator output is used primarily to provide a suitable input for adjusting the probe compensation, and to provide an input for making the preamplifier gain adjustment.

### Z-Input

An input to the CRT cathode is called the Z-input. A signal applied to this input will vary the intensity of the trace. The Z-input is useful for inserting timing markers or for finding the time relation of two signals.

Because the input is coupled to the CRT cathode, a positive signal reduces the intensity of the trace, and a negative signal makes the trace brighter. The Z-input is also referred to as trace-brightness modulation, or intensity modulation.

#### *Connections*

Intensity modulation is accomplished by connecting a signal source to a pair of binding posts located at the rear of the instrument. One binding post provides instrument ground, and the other post feeds the CRT cathode through a resistor capacitor network. A metal strap between the two binding posts must be removed prior to connecting the modulating signal.

Some instruments have a switch (CRT cathode selector) associated with the Z-input. One position of this switch activates the binding posts to allow intensity modulation. The other switch position is used with dual trace plug-in units. The cathode selector switch is adjacent to the binding posts.

### Plug-In Units

To increase oscilloscope versatility, the Tektronix 500 series instruments employ plug-in units. The plug-in units always house the vertical preamplifier and may also contain controls and circuitry for special functions. Five types of plug-in units are presently supplied as IBM office tools. A description of each type of plug-in

unit is given in the Plug-in Units for Wide-Band Oscilloscopes Section.

### *Special Functions*

Special presentations provided by plug-in units are dual trace display and differential display.

Dual trace plug-in units contain two separate preamplifiers. The main vertical amplifier is fed alternately by the two preamplifiers. A high-speed switching circuit ("chopper") provides the connection between the preamplifier and the main vertical amplifier. Due to the high speed of the switching operation, the two input waveforms appear to be displayed simultaneously.

A dual trace display allows the operator to make the closest possible comparison of two waveforms.

A differential plug-in unit also contains two preamplifiers. In this case, however, the output of one preamplifier is inverted and added to the output of the other preamplifier. The resulting waveform is fed to the main vertical amplifier.

A differential display shows the instantaneous voltage difference between the two points connected to the oscilloscope inputs. For example, if the two points under test are positive 20 volts (with respect to oscilloscope ground) at the same instant, the resulting display will be at the reference line (no vertical deflection). However, if one test point is positive 20 volts at the same instant the other point is negative 20 volts, the vertical display will indicate 40 volts.

A differential display is used primarily to observe the output of push-pull circuits, although certain time relations can be found very accurately with this presentation. For example, if a narrow pulse occurs during a wider pulse, a differential display will show in the wide pulse a gap that represents the narrow pulse. The time relation of the two pulses, therefore, is readily determined.

### **Single Sweep**

Some Tektronix oscilloscopes are capable of generating single sweep displays. In this mode of operation, a reset key must be depressed each time a sweep is desired. An indicator lamp is lit whenever the reset key is depressed, indicating that the time base generator is ready. The next trigger into the oscilloscope causes one sweep, at which time the ready lamp is extinguished. No more sweeps can occur until the reset key is again depressed.

The single sweep mode of operation is selected by a position of the horizontal display switch; the exact procedure varies with the oscilloscope. Operating instructions are given in sections of the manual referring to specific oscilloscope models.

### *Applications*

The primary application for single sweep operation is in photographing CRT displays. However, two other applications are significant.

Non-repetitive waveforms, such as damped waves, can best be observed by using single sweep operation.

Single sweep operation is also useful for monitoring test points. For example, if random noise waveforms are present at a certain test point, the triggering control can be set so that only the noise signals will cause a sweep. The oscilloscope is connected to the test point and set for single sweep operation. The operator can then leave the instrument to monitor the test point. Later, the operator can determine if the unwanted waveform occurred by checking the ready indicator.

### **Sweep Delay**

Some Tektronix oscilloscopes include provisions for sweep delay. This feature allows the operator to obtain an accurate time delay between the trigger and the start of the sweep. The amount of time between the trigger and the actual start of the sweep is controlled by the operator, and may be as short as one microsecond or as great as ten seconds.

The sweep delay feature solves two special problems. The first problem arises in obtaining a single sweep of a trigger. Although the trigger generator is set for single sweep, the operator cannot select one waveform out of a group of waveforms if the amplitudes are similar. Figure 13 shows a group of pulses where the desired display could be obtained by using the sweep delay feature. A single sweep of a group of pulses often results whenever the amplitudes of a number of circuits are ordered together.

The desired display of Figure 13 is effectively a magnification of the normal presentation. Using the sweep delay feature, magnifications as high as 100 are obtainable.

The second problem solved by sweep delay is obtaining accurate time readings. Although time is displayed on the viewing screen, time measurements depend a great deal on the operator's skill. For example, two pulses are 873 microseconds apart. If played on a 100 microsecond/centimeter time base, the distance between pulses, therefore, is 8.73 centimeters. The accuracy of the reading depends on the operator's ability to measure the distance accurately.

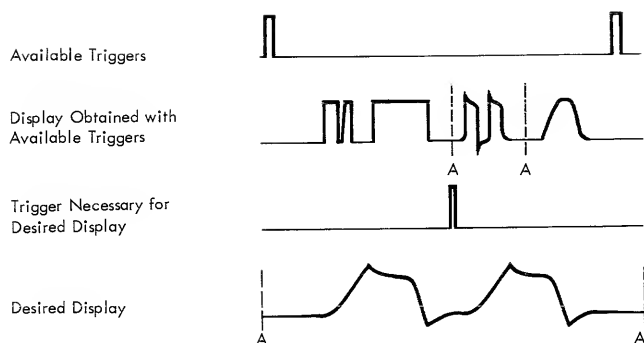


Figure 13. Delayed Trigger

operator's ability to interpolate the distance between scale divisions. When the sweep delay feature is used for the same measurement, the distance (8.73 centimeters) is read directly on a mechanical dial. The dial is calibrated in centimeters and hundredths of centimeters, making an accurate measurement possible without interpolation.

### Delay Time Base Generator

An oscilloscope with the sweep delay feature employs two time base generators and two trigger generators. The second pair of circuits provides a delayed trigger to the primary time base generator.

The primary, or normal, time base generator is called the main sweep or time base A. The secondary, or delay, time base generator is called the delaying sweep or time base B.

With one exception, the main sweep circuits of an oscilloscope with sweep delay are identical to the sweep circuits of other oscilloscopes. The exception is a circuit called the lock-out multivibrator. This circuit functions as an on-off switch for the main sweep. One condition of the lock-out multivibrator prevents operation of the main sweep. In this condition, the sweep generator is locked-out, or unarmed. The other condition of the lock-out multivibrator allows the main sweep to operate normally. The lock-out multivibrator is the same circuit used in single sweep operation. The lock-out multivibrator must be switched for each sweep desired, because the sweep returns it to its off condition. In single sweep, the lock-out multivibrator is fed by the reset key. In sweep delay, however, the lock-out multivibrator is fed from the delaying sweep circuits.

The delaying sweep controls and circuits are essentially the same as those of the main sweep. There is, however, no lock-out multivibrator associated with the delaying sweep.

### Operating Modes

Only one time base generator may be connected to the horizontal amplifier at any one time. The CRT control grid, however, may receive an unblanking pulse from one or both time base generators (Figure 14).

The operator may select any one of four modes of operation. The four modes differ only in the manner the two sawtooth waveforms and the two unblanking waveforms are used. Mode choice is made primarily by using the horizontal display switch.

The first mode is A only. In this mode the sawtooth produced by the main sweep circuits is used for horizontal deflection, and the main sweep unblanking pulse is used to unblank the CRT. The delaying sweep circuits are not used in any manner.

In the second mode, B only, the delaying sweep is used for deflection and unblanking. The main sweep circuits are not used in any manner.

The third mode is B intensified by A. In this mode, the delaying sweep sawtooth is used to deflect the beam, but unblanking is the result of both unblanking waveforms (Figure 14). Another factor in this mode is the lock-out multivibrator. Unlike in the first two modes, the lock-out multivibrator is brought into operation and fed by the delaying sweep circuits.

To use B intensified by A, the trigger is fed into the delaying sweep circuits. When triggered, the delaying sweep starts, and can be seen on the viewing screen. At some point during the delaying sweep, however, an arming pulse is sent from the delaying sweep to the lock-out multivibrator. The main sweep then starts, brightening the trace for its duration. Normally, the main sweep is set for a shorter time duration than the delaying sweep when using B intensified by A. The

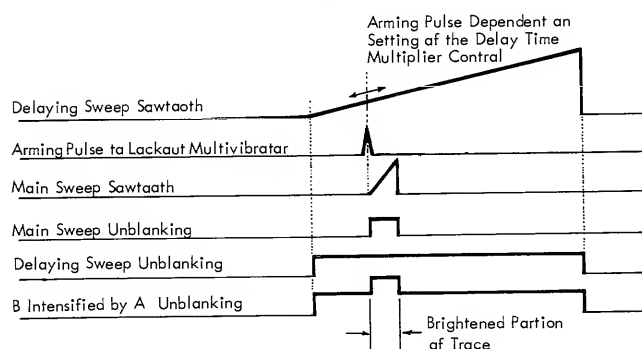


Figure 14. Time Base Generator Waveforms

resulting display is a normal presentation with a brightened portion. The delay time multiplier control allows the operator to move the brightened portion to any point on the trace (Figure 14). The delay time multiplier control accurately indicates the position of the brightened portion in centimeters and hundredths of centimeters.

Two sub-modes may be selected when using B intensified by A. If the stability control is in the free-running position, the main sweep will start immediately upon receiving the arming pulse. With the control in the synced position, however, the start of the main sweep is further delayed until the main sweep receives a trigger. The delay time multiplier control does not indicate the position of the brightened portion if the main sweep stability control is in its synced position.

The fourth mode is A delayed by B. In this mode, main sweep deflection and unblanking are used, but the lock-out multivibrator is left in operation. The main sweep, therefore, can be started only after an arming pulse arrives from the delaying sweep. The result of this mode is a full screen display of the brightened portion seen in B intensified by A. A delayed by B is often considered a magnification of the B intensified by A display. The amount of magnification is determined by the ratio of the two sweep speeds. The two sub-modes that apply to B intensified by A also apply to A delayed by B.

### *Delay Pick-off*

The arming pulse to the lock-out multivibrator is generated by the delay pick-off circuit. This circuit allows the operator to generate the arming pulse at any point on the delaying sweep (Figure 14) by permitting the operator to select a dc voltage level with the delay time multiplier control. This voltage is then compared with the delaying sweep sawtooth. When the two voltages are equal, a pulse is generated and sent to the lock-out multivibrator.

### *Applications*

To examine a waveform closely, the sweep must be triggered immediately preceding the start of the waveform (if the waveform, itself, cannot be used to trigger the sweep). If any appreciable amount of time elapses before the start of the waveform, the waveform displayed will be so narrow that its details cannot be seen. For example, assume that a waveform two microseconds wide is to be viewed. If the sweep is started 95 microseconds before the waveform occurs, the waveform can be seen only on a ten microsecond/centimeter (or slower) time base. The display of the waveform will be 1/5 of a centimeter in width.

Whenever a trigger immediately prior to the waveform is not available, the sweep delay should be used. For this application, the trigger is fed to the delay time base generator, main time base generator is used to deflect the trace. The point at which the main time base is synchronized is controlled by the operator through the delay time multiplier control. Effectively, a normal oscilloscope display is being used with a variable time delay inserted for the trigger. This operation should be considered as A delayed by B (main sweep delayed).

To illustrate the desirability of an A delayed by B presentation, consider examining a single bit output from drum or core storage. Using A delayed by B, the output of each address may be examined at a time. To move to the next address being read, it is necessary only to advance the delay time multiplier control. The address under observation can be determined at any time by switching to B intensified by A.

The sweep delay feature should also be used whenever exact time measurements are required. An accurately calibrated delay is inserted between the trigger and the start of the sweep. To make accurate time measurements, both B intensified by A and A delayed by B modes are normally used.

The B intensified by A mode is used for two functions. First, this mode allows the operator to position the main sweep. The location of the main sweep is indicated by the brightened portion of the trace in B intensified by A mode. By using the delay time multiplier control, the operator can position the main sweep to the spot. The position of the main sweep is only approximately correct at this point. Much finer positioning is obtained in A delayed by B. Preliminary positioning of the main sweep is important, however. Due to the high magnification obtainable in A delayed by B, the correct position may be impossible until the position has been tentatively set.

The second function of B intensified by A is for the examination of the triggering waveform. This is significant only if the time measurement is taken in relation to the trigger. In such cases, the trigger must be examined to determine the exact point of the triggering waveform at which triggering is taking place. Triggering controls may then be manipulated so that triggering occurs at the desired point.

To make time measurements using sweep delay, obtain a B intensified by A display. If the triggering waveform is to be the reference time, view the trace to determine the exact reference point. Turn the delay time multiplier control until the second measurement point is brightened. In some cases, the B intensified by A display will give enough accuracy for the measurement. If so, note that the left-most edge of the

ened portion is to be placed on the second time measurement point. The delay time multiplier control can now be read to determine the exact position of the brightened portion.

Where more accuracy is desired, the operator should switch to A delayed by B. The delay time multiplier can now be more accurately positioned by aligning the second measurement point with the start of the displayed sweep (left-most edge).

Whenever the triggering waveform is not to be used as a reference, two separate readings are obtained. For example, assume that the time between two displayed points is desired. The first point is measured and found to be 3.37 centimeters from the trigger. The second point is 9.79 centimeters from the trigger. The distance

between the points, therefore, is 9.79 minus 3.37, or 6.42 centimeters. The time between the points may now be found by multiplying 6.42 by the delaying sweep time/div setting. Although the exact point of triggering is not significant in this case, the triggering controls must not be changed between the two readings.

The main sweep stability control must be in the free-running position whenever time measurements are made. The synced position is used only to eliminate waveform jitter for general viewing. Waveform jitter is a horizontal shifting of the waveform, and occurs if the waveform under observation is not stable. Poor stability in this case means that the time between the trigger and the waveform under observation is varying.

## Portable Oscilloscopes

Two portable Tektronix oscilloscopes, 310 and 310A, are presently in use. The two models are similar, the 310A being an improved version of the 310.

### Tektronix 310

The Tektronix 310 is a 23½ pound, portable oscilloscope, measuring 10 x 6¾ x 17 inches. The instrument consumes 175 watts of power from a 105 to 125 volt power line at 60 to 800 cycles per second. The 310 uses a three-inch CRT with a graticule divided into eight vertical and ten horizontal ¼-inch divisions.

The vertical amplifier has a frequency response of approximately dc to four megacycles. Rise time is .09 microsecond.

Sweep speeds from .6 second/division to .1 microsecond/division may be obtained.

Triggering occurs with waveforms from dc to five megacycles. Minimum trigger amplitude is .2 volt for external triggers and ½ division of vertical deflection for internal triggers.

### *Controls and Jacks*

The controls and jacks of the 310 are divided into five groups. The first three groups, which are outlined and labeled on the front panel, are: vertical amplifier, time base, and calibrator (Figure 15). In addition, there are five controls and an indicator that are not outlined; these are the non-labeled group. The last group consists of controls and jacks on the rear panel.

#### VERTICAL AMPLIFIER GROUP

**INPUT.** This jack accepts the test probe connector. The waveform to be observed enters the instrument at this point.

**AC/DC.** This two-position switch accepts the entire vertical signal (DC), or removes the DC component (AC).

**VOLTS/DIV.** This dual control selects the vertical sensitivity. The larger black control provides 12 steps of sensitivity from .01 to 50 volts/division. These settings are not correct unless the smaller red control is

fully clockwise (calibrated position). The red control gives continuously variable sensitivities between the 12 steps. The red (variable) control lights the NON-CALIBRATED indicator lamp when the control is other than extreme clockwise.

#### TIME BASE GROUP

**TRIGGER.** This dual switch selects the trigger source, slope, and mode. The larger black control is a six-position switch to select the plus or minus slope of any one of three trigger sources (line, internal or external). The smaller red control is a three-position switch for selecting one of three triggering modes (AC, DC or auto).

**STABILITY-TRIG LEVEL.** This dual control sets the sweep multivibrator bias and the level at which triggering will occur. The larger black control is a potentiometer that sets the triggering level. The center position of this control is zero and allows triggering with the smallest voltages. As the control is moved clockwise from center, increasing positive voltages are required to trigger. As the control is moved counterclockwise from center, increasing negative voltages are required to trigger. The red control is a potentiometer for setting the sweep multivibrator for free-running, synced, or disabled operation.

**HORIZ INPUT.** This three-position switch controls the horizontal amplifier. In the ×1 position, the horizontal amplifier is fed from the sweep generator, and the gain of the amplifier provides ten divisions of deflection. The ×5 position increases the horizontal amplifier gain to provide 50 divisions of deflection. The horizontal input position disconnects the sweep amplifier and connects the horizontal input jack (on rear panel) to the input of the horizontal amplifier.

**TRIG INPUT.** This jack accepts a triggering waveform when the TRIGGER control is set for an external trigger source.

**TIME/DIV.** This dual control selects the amount of time represented by each horizontal division. The larger black control is an 18-position switch selecting one of 18 sweep speeds between .5 microsecond and .2 second per division. The smaller red control provides uncalibrated sweep speeds between the 18 steps. This

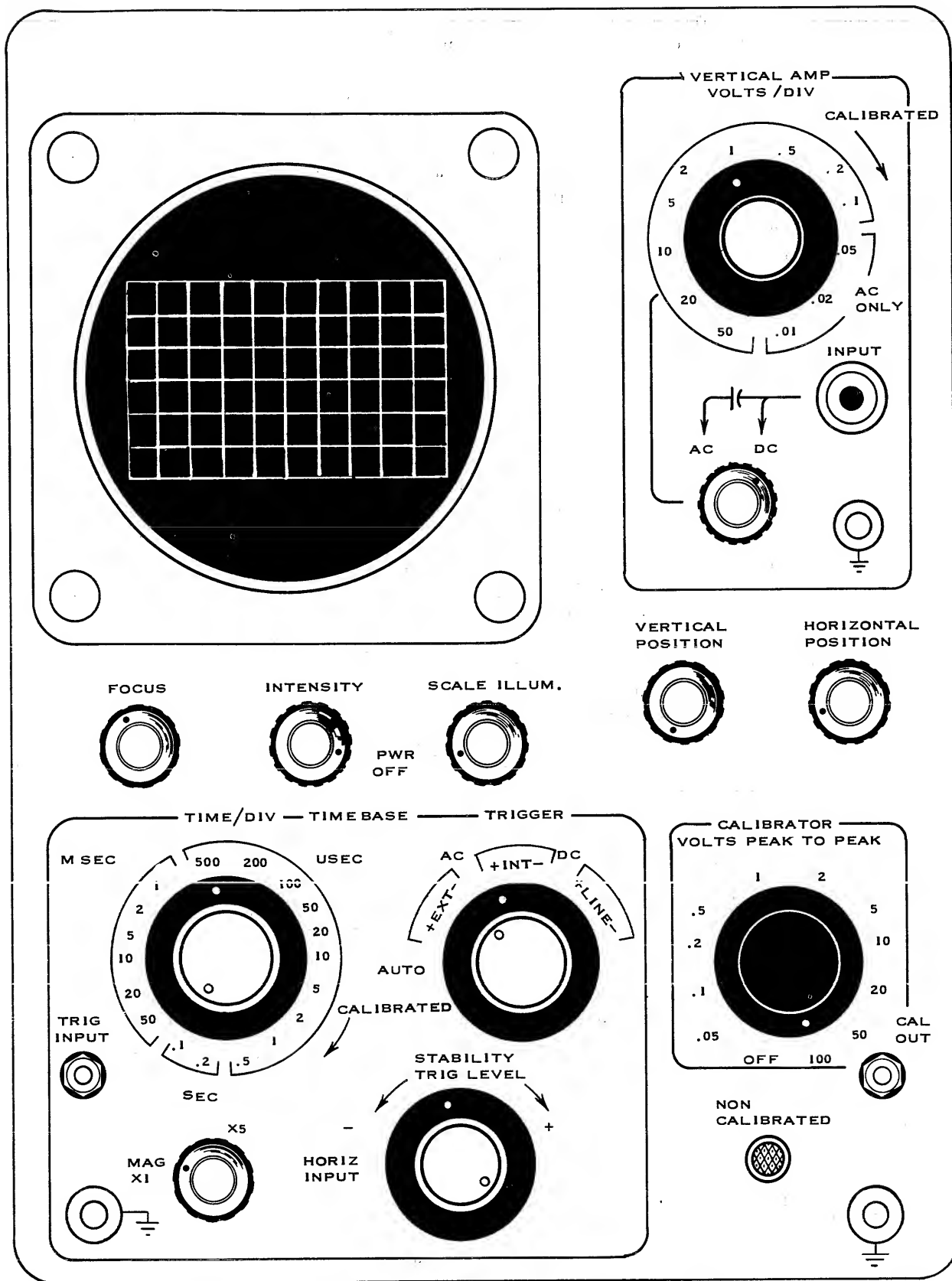


Figure 15. 310 Front Panel

control lights the NON-CALIBRATED lamp if the control is not in its extreme clockwise (calibrated) position.

#### CALIBRATOR GROUP

**CAL OUT.** This jack is connected to the voltage calibrator output.

**CALIBRATOR.** This 12-position switch turns the calibrator off or selects one of 11 calibrator amplitudes. The available amplitudes are between .05 and 100 volts. The selected amplitude is directed to the CAL OUT jack.

#### NON-LABELED GROUP

**FOCUS.** This potentiometer controls the sharpness of the spot or trace.

**INTENSITY.** This potentiometer controls the brilliance of the spot or trace.

**SCALE ILLUM.** This control varies the brilliance of graticule illumination; it also serves as the instrument power on/off switch. Extreme counter-clockwise rotation removes power from the 310.

**NON-CALIBRATED.** This indicator lamp warns the operator of a non-calibrated scale. This indicator is lit unless both the variable VOLTS/DIV and the variable TIME/DIV are extreme clockwise.

**VERTICAL POSITION.** This potentiometer shifts the trace up or down on the viewing screen. This control allows the operator to set the trace to a reference point before connecting a vertical signal to the instrument.

**HORIZONTAL POSITION.** This potentiometer shifts the trace left or right on the viewing screen.

#### REAR PANEL GROUP

**CRT CATHODE.** These two jacks (one is ground) facilitate intensity modulation. A metal strap between the two jacks must be removed prior to connecting a signal to this input.

**EXT HORIZ INPUT.** These two jacks (one is ground) are connected to the horizontal amplifier input when the HORIZ INPUT switch is in the horizontal input position.

**HORIZ GAIN.** This potentiometer is connected as a variable attenuator for any signal connected to the EXT HORIZ INPUT jack.

**MAG CENTER.** This potentiometer controls the horizontal position of the  $\times 5$  display. The adjustment is set to provide equal expansion right and left of center; that is, the center of a  $\times 1$  display and the center of a  $\times 5$  display show the same portion of a waveform.

**SWEEP CAL.** This control calibrates low and medium sweep speeds. This control should not be adjusted unless an accurate source of one-millisecond markers is available.

**VERT GAIN ADJ.** This potentiometer sets the vertical amplifier gain. Adjust this control with a .5 volt signal from the CAL OUT jack applied. Set the VOLTS/DIV to .1 and the variable VOLTS/DIV fully clockwise. Adjust for exactly five major divisions of vertical deflection.

**ASTIG.** This control assists focusing by affecting the beam shape. The adjustment should be made with a point displayed near the center of the viewing screen. Adjust for a round point of light; then alternately adjust FOCUS and ASTIG for the smallest round point obtainable.

### 310 Operation

The 310 power plug has three prongs. The third prong carries a ground lead for the oscilloscope chassis. Normally, no extra ground lead is necessary.

**CAUTION:** Never connect the 310 ground jacks to a voltage potential. Doing this on instruments with a grounded power plug results in arcing and burning out some component.

A thermal cut-out temporarily removes power from the 310 when overheated. Although the instrument can be operated in an upright position (front panel up), best cooling is obtained in the normal operating position. In either case, air flow around the 310 must not be restricted.

If difficulty is encountered in obtaining a trace, do the following:

1. Remove the input signal.
2. Turn STABILITY completely clockwise.
3. Turn INTENSITY completely clockwise.
4. Turn HORIZ INPUT to  $\times 1$ .
5. Center VERTICAL POSITION and HORIZONTAL POSITION controls.

If a trace is not visible after these steps, the instrument is inoperative.

When observing a waveform, trace width should be uniform across the entire viewing screen. If not, the ASTIG control should be adjusted. Maladjustment of this control may result in a football-shaped beam. This beam is narrow when deflected horizontally, but wide when deflected vertically.

Often, a misleading display is presented because an improper trigger is chosen. The two most common triggering errors are using the internal trigger source on non-repetitive waveforms, and using an external trigger that is too high in frequency.

The internal trigger source must not be used, unless the waveform is repetitive. For example, assume that a test point to be viewed has groups of equal amplitude pulses. If the vertical waveform is used for a trigger source, a continuous line of pulses will be seen because the trigger generator recognizes any one of the pulses



as a trigger. Therefore, sweeps are started by random pulses within the group, causing the groups of pulses to be positioned differently on the viewing screen. Because a great number of sweeps are viewed at any one time, the pulses appear to be occurring continuously. If the pulse groups are narrow in relation to the gaps, the groups will appear to consist of twice the actual number of pulses. To see groups of pulses correctly, an external trigger must be used.

If an external triggering source is used, it must be equal to or slower than the frequency of the waveform being viewed. The sweep must always start at the same time in relation to the beginning of a waveform. If several triggers occur during a waveform, successive sweeps will present different portions of the signal. The resulting display, therefore, is a confusing pattern.

A confusing pattern on the oscilloscope may be the result of a number of conditions. The two examples given represent common operating errors, but are not the only conditions that present a confusing pattern. A thorough understanding of the 310 block diagram (Figure 16) and familiarity with the function of each control is the best insurance for obtaining accurate display.

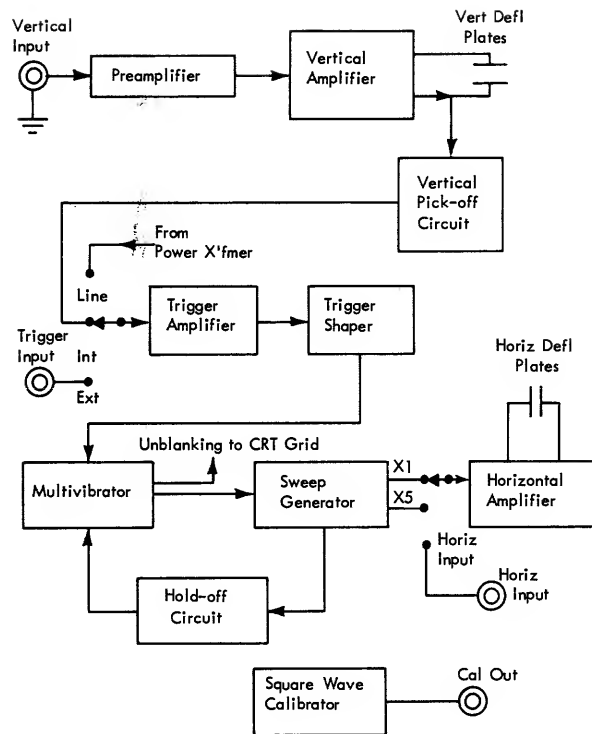


Figure 16. Tektronix 310

## Tektronix 310A

The Tektronix 310A is an improved version of the 310. Although internal circuitry is somewhat different, the logical function of the two instruments is identical. The 310A contains only two operating differences from the 310: the addition of a preset position to the STABILITY control, and replacement of the NON-CALIBRATED indicator by two indicators.

### Preset

A switch removes the STABILITY potentiometer from the circuit and substitutes a preset potentiometer. Extreme counter-clockwise rotation of the STABILITY control energizes this switch. The preset potentiometer is

screwdriver-adjusted for synced, or triggered operation. The adjustment is made from the front panel and is labeled PRESET ADJUST.

### Indicators

The NON-CALIBRATED indicator on the 310 is replaced by two indicators, UNCALIBRATED TIME BASE and UNCALIBRATED VERTICAL. The UNCALIBRATED TIME BASE indicator is lit whenever the variable TIME/DIV control is not extreme clockwise. The UNCALIBRATED VERTICAL indicator is lit whenever the variable VOLTS/DIV is not extreme clockwise.

## Wide-Band Oscilloscopes

This section provides specific information on two wide-band oscilloscopes (531 and 531A) presently in use. Wide-band instruments with the sweep delay feature are discussed in the next section. The 531A is an improved version of the 531, and is therefore similar to it.

### Tektronix 531

The Tektronix 531 is an accurate, versatile, laboratory instrument. A five-inch CRT is used with a graticule marked with six vertical and ten horizontal one-centimeter divisions. The instrument measures  $24 \times 13 \times 16\frac{3}{4}$  inches, and consumes approximately 500 watts of power. The 531 may be operated on 105 to 125 or 210 to 250 volts at 50 to 60 cycles.

The vertical amplifier of the 531 has a bandpass of approximately dc to 15 megacycles, with a rise time of 23 nanoseconds. Sweep speeds from .1 microsecond/centimeter to 5 seconds/centimeter are obtained in 24 steps with an accuracy of three percent. Sweep speeds from .02 microsecond/centimeter to 12 seconds/centimeter are obtainable with lesser accuracy.

#### *Controls and Jacks*

The 531 employs a plug-in unit that houses the pre-amplifier and its controls, as well as the vertical positioning control. Five types of plug-in units are presently being supplied for use in wide-band oscilloscopes. A discussion of each is presented in the Plug-in Units for Wide Band Oscilloscopes Section.

The remaining controls and jacks of the 531 are divided into three groups. The first group consists of controls and jacks not grouped on the front panel (Figure 17). The second group consists of the controls and jacks enclosed by a heavy line on the front panel and labeled "sweep." The third group consists of rear panel jacks.

#### NON-GROUPED CONTROLS AND JACKS

**POWER ON.** This toggle switch controls AC power. In the on position, a red indicator lamp is lit to signify that AC power is applied. DC power is applied approximately 30 seconds later by a time-delay relay.

**CAL OUT.** This jack is connected to the square wave calibrator output.

**SQUARE WAVE CALIBRATOR.** This dual control turns the calibrator off or provides one of 18 amplitudes at the CAL OUT jack. The larger black control is a nine-

position switch with positions from .2 to 100. The smaller red control is a three-position switch to turn the calibrator off or to determine that the larger control positions are volts or millivolts.

**HORIZONTAL POSITION AND VERNIER.** This dual control moves the trace back and forth across the viewing screen. The larger black control is a coarse adjustment, and the smaller red control is a vernier or fine adjustment.

**HORIZONTAL DISPLAY.** This three-position switch selects the input to the horizontal amplifier. The positions are internal sweep, external sweep  $\times 1$ , and external sweep  $\times 10$ .

**EXTERNAL SWEEP ATTENUATOR 10:1.** This potentiometer provides variable attenuation of an external sweep waveform. This control is independent of the  $\times 10$  attenuation available with HORIZONTAL DISPLAY. By using the two attenuators in conjunction, an attenuation factor of 100 is obtainable.

**EXTERNAL SWEEP IN.** This jack accepts an external sweep waveform.

**SAWTOOTH OUT.** This jack provides the internal sweep waveform. The sawtooth is positive-going, approximately 150 volts peak.

**+ GATE OUT.** This jack provides a positive 20-volt pulse with a duration equal to internal sweep sawtooth.

**FOCUS.** This potentiometer controls the size of the electron beam, and thus, the size of the point of light caused by the beam.

**INTENSITY.** This potentiometer controls the brilliance of the display.

**ASTIGMATISM.** This potentiometer controls the shape of the electron beam. It is used with the focus control to obtain a small, round point of light.

**SCALE ILLUM.** This potentiometer controls the brilliance of the graticule lights.

Four indicating lamps above the CRT indicate beam position when it is not visible. The indicators are labeled with arrows.

#### SWEEP CONTROLS AND JACKS

**TRIGGER INPUT.** This jack accepts an external triggering waveform.

**TRIGGERING MODE AND TRIGGERING SLOPE.** This dual control selects the trigger source, the trigger slope, and the triggering mode. The larger black control is a six-position switch that selects the positive-going or negative-going portion of one of three triggering sources: external, internal, and line. The smaller red control

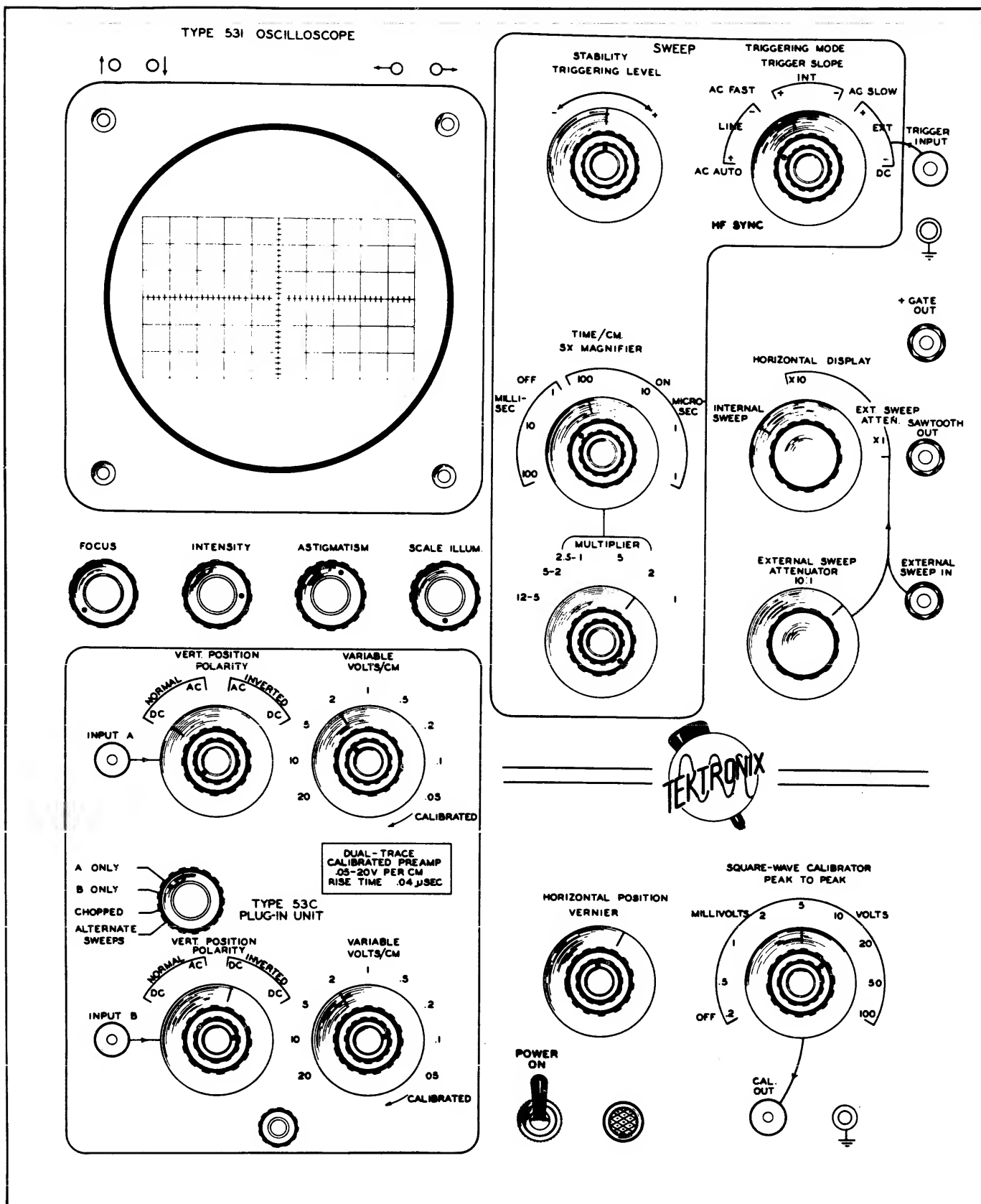


Figure 17. 531 Front Panel

selects one of five triggering modes: DC, AC slow, AC fast, AC auto, and HF sync.

**STABILITY AND TRIGGERING LEVEL.** This dual control sets the sweep multivibrator bias and the amplitude at which triggering will occur. The larger black control (TRIGGERING LEVEL) controls the triggering amplitude. Triggering occurs at the lowest amplitudes when this control is in its center position. Clockwise rotation (from center) results in triggering at increasing positive voltages, and counter-clockwise rotation (from center) results in triggering at increasing negative voltages. The smaller red control (STABILITY) controls operation of the sweep generator. The extreme clockwise position causes the sweep to be free-running; the extreme counter-clockwise position disables the sweep generator; a position between the extremes results in synced, or triggered, operation.

**TIME/CM AND 5× MAGNIFIER.** This dual control affects sweep speed. The larger black control (TIME/CM), which sets the basic sweep speed, is a seven-position switch with positions from .1 microsecond to 100 milliseconds per centimeter. The smaller red control is an on-off switch for the 5× MAGNIFIER. When the 5× MAGNIFIER is on, the sweep is 50 centimeters long. The sweep is 10 centimeters long with the 5× MAGNIFIER off. To find the actual time/centimeter with the 5× MAGNIFIER on, divide the TIME/CM control setting by five.

**MULTIPLIER.** This dual control modifies TIME/CM settings. The larger black control is a six-position switch. Three positions of the switch (1, 2, and 5) are used directly to multiply the TIME/CM setting. For these three positions, the smaller red control is inoperative. The red control provides variable multiplication when the black control is in any one of the other three positions (1-2.5, 2-5, 5-12).

#### REAR PANEL JACKS

**CRT CATHODE.** These two jacks on the rear panel accept an intensity modulating input. One jack provides ground and the other is coupled to the CRT cathode. A metal strap between the two jacks must be removed before connecting the input.

### 531 Operation

The 531 power plug has three prongs. The third prong carries a ground lead for the oscilloscope chassis. Normally, no extra ground lead is necessary.

**CAUTION:** Never connect the 531 ground jacks to a voltage potential. Doing this on instruments with a grounded power plug results in arcing and burning out some component.

A thermal cut-out temporarily removes power from the 531 when overheated. The instrument is cooled by forced air drawn through an air filter on the rear of the oscilloscope. To prevent overheating, the air filter must be kept clean and unobstructed.

If difficulty is encountered in obtaining a trace, do the following:

1. Make certain that power is applied.
2. Remove the input signal.
3. Turn STABILITY completely clockwise.
4. Turn HORIZONTAL DISPLAY to internal sweep.
5. Set INTENSITY completely clockwise.
6. Center VERTICAL POSITION and HORIZONTAL POSITION controls.

If a trace is not visible after these steps, the instrument is inoperative.

When observing a waveform, trace width should be uniform across the entire viewing screen. If not, the ASTIGMATISM control should be adjusted. Maladjustment of this control may result in a football shaped beam. This beam is narrow when deflected horizontally, but wide when deflected vertically.

Often, a misleading display is presented because an improper trigger is chosen. The two most common triggering errors are using the internal trigger source on non-repetitive waveforms, and using an external trigger that is too high in frequency.

The internal trigger source must not be used, unless the waveform is repetitive. For example, assume that a test point to be viewed has groups of equal amplitude pulses. If the vertical waveform is used for a trigger source, a continuous line of pulses will be seen because the trigger generator recognizes any one of the pulses as a trigger. Therefore, sweeps are started by random pulses within the group, causing the groups of pulses to be positioned differently on the viewing screen. Because a great number of sweeps are viewed at any one time, the pulses appear to be occurring continuously. If the pulse groups are narrow in relation to the gaps, the groups will appear to consist of twice the actual number of pulses. To see groups of pulses correctly, an external trigger must be used.

If an external triggering source is used, it must be equal to, or slower than, the frequency of the waveform being viewed. The sweep must always start at the same time in relation to the beginning of a waveform. If several triggers occur during a waveform, successive sweeps will present different portions of the signal. The resulting display, therefore, is a confusing pattern.

A confusing pattern on the oscilloscope may be the result of a number of conditions. The two examples given represent common operating errors, but are not

the only conditions that present a confusing pattern. A thorough understanding of the 531 block diagram (Figure 18) and familiarity with the function of each control is the best insurance for obtaining accurate displays.

## Tektronix 531A

Because the Tektronix 531A is similar to the 531, only differences are described. Major differences are control labeling and additional indicating lamps. Logical functions contain no significant differences.

### Labeling

Several front panel labels are different on the two oscilloscopes. The following table correlates the labeling of the two front panels.

TEKTRONIX 531	TEKTRONIX 531A
Sweep	Time Base
External Sweep Attenuator	External Horizontal Attenuator
External Sweep In	Horizontal Input
Square Wave Calibrator	Amplitude Calibrator

In addition to these changes, f-stop settings are marked on the SCALE ILLUM control of the 531A. These markings are used in photographing displays.

### Control and Jack Changes

**MULTIPLIER.** No MULTIPLIER control is on the 531A.

**TIME/CM AND 5× MAGNIFIER.** This control has been changed to TIME/CM AND VARIABLE. The VARIABLE control provides uncalibrated sweep speeds that are continuously variable between the steps of the TIME/CM control. The slowest sweep speed is extended to approximately 12 seconds/centimeter by the VARIABLE control. An indicator, MAG ON, is lit whenever a magnified sweep is selected. Another indicator, UNCALIBRATED, is lit whenever the VARIABLE control is not fully clockwise. The 531A 5× MAGNIFIER is controlled by the HORIZONTAL DISPLAY switch.

**STABILITY AND TRIGGERING LEVEL.** A preset position has been added to the STABILITY control. The extreme counter-clockwise position (preset) energizes a switch that inserts a screwdriver-adjusted potentiometer in place of the STABILITY control. The screwdriver adjustment is made from the front panel and is labeled PRESET ADJUST. The potentiometer is adjusted to the synced, or triggered, stability setting.

**AMPLITUDE CALIBRATOR.** One control replaces the two controls of the 531. The control is a 19-position switch. One position is used to turn the calibrator off and the other positions select amplitudes from .2 millivolt to 100 volts in 18 steps.

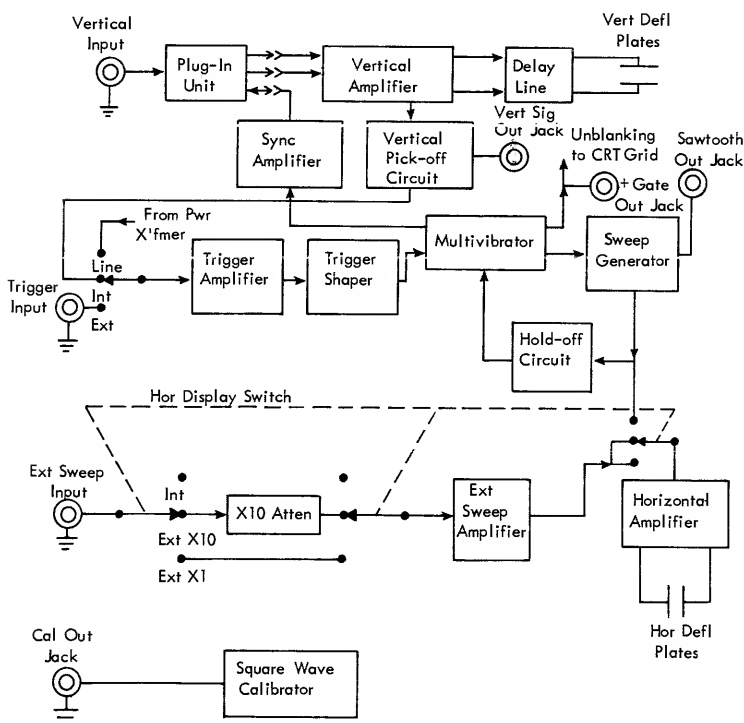


Figure 18. Tektronix 531

## Wide-Band Oscilloscopes with Sweep Delay

This section provides specific information on three sweep delay oscilloscopes (535, 535A, and 545A) presently in use. The 535 is the same instrument as the 531 with the sweep delay feature added. The 535A is an improved version of the 535, and only the changes are described. The 545A is included with the 535A because the controls of the two instruments are identical.

### Tektronix 535

The Tektronix 535 is a 531 with a sweep delay feature added. The instrument weighs 65 pounds and has the same dimensions as the 531. Only controls and jacks different from those of the 531 are discussed.

#### *Controls and Jacks*

In addition to the three groups of controls on the 531, the 535 contains a fourth group of controls, labeled delaying sweep (Figure 19). The delaying sweep controls affect a second time base generator that has been added to provide a delay for the main sweep.

#### DELAYING SWEEP CONTROLS

**STABILITY AND TRIGGERING LEVEL.** This dual control sets the delaying sweep multivibrator bias and the level of triggering for the delaying sweep. The **TRIGGERING LEVEL** control is identical to the corresponding main sweep control. The **STABILITY** control functions as a variable external sweep attenuator when **HORIZONTAL DISPLAY** is set to external sweep.

**TIME/CM OR DELAY TIME AND LENGTH.** This dual control sets the speed and length of the delaying sweep. The larger black control is the 12-position **TIME/CM OR DELAY TIME** switch. Positions are from two microseconds to ten milliseconds. The smaller red control adjusts the length of the delaying sweep from four centimeters to ten centimeters. This control does not affect sweep speed, but does affect sweep repetition rate. For example, if the **TIME/CM (DELAY TIME)** setting is five microseconds and the sweep length is ten centimeters, the total time for one sweep is 50 microseconds. If the sweep length is decreased to four centimeters, the total time for one sweep is reduced to 20 microseconds, allowing the next sweep to start 30 microseconds earlier than before.

**DELAY TIME MULTIPLIER.** This control multiplies the **TIME/CM OR DELAY TIME** settings. This is a ten-turn helipot calibrated in centimeters and hundredths of centimeters. It accurately shows the operator how many centimeters of delaying sweep have occurred prior to the triggering of the main sweep.

#### OTHER CONTROLS AND JACKS

**SLOPE.** This toggle switch, with plus and minus positions, determines whether the delaying sweep will start on the rising or falling portion of the triggering waveform.

**ATTEN.** This toggle switch, with  $\times 1$  and  $\times 10$  positions, affects delaying sweep triggers or external sweep input waveforms.

**TRIGGER OR EX SWEEP IN.** This jack accepts the delaying sweep trigger or an external sweep waveform. The signal is routed to the proper circuitry by the **HORIZONTAL DISPLAY** switch.

**DEL'D TRIGGER FROM MAIN OR DEL'G SWEEP.** This jack is connected to the output of the delay pick-off circuit. The pulse is approximately five volts in amplitude.

**+ GATE DEL'G SWEEP.** This jack provides a positive 20-volt pulse with a duration equal to the delaying sweep sawtooth.

**6.3V 1A AC.** This jack is connected to a filament winding of the power transformer.

**RESET MAIN SWEEP.** This is a reset key for single sweep operation.

**HORIZONTAL DISPLAY.** This switch of the 531 has been changed in the 535. The 535 switch has four positions (Figure 20):

1. **External Sweep.** This position connects a front panel jack, **TRIGGER OR EXT SWEEP IN**, to the input of the horizontal amplifier. CRT unblanking is connected to +100 volts to provide continuous unblanking. Neither main nor delaying sweep circuits are used.
2. **Main Sweep Normal.** This position provides a normal oscilloscope display using the main sweep only. The delay pick-off circuit is fed by the main sweep, providing a delayed trigger at the **DEL'D TRIGGER** front panel jack.
3. **Main Sweep Delayed.** The delaying sweep is used to trigger the main sweep in this position. The triggering waveform is fed to the delaying sweep that controls the lock-out multivibrator. The amount of delay is determined by the **TIME/CM OR DELAY TIME** setting, multiplied by the **DELAY TIME MULTIPLIER** setting. This position is also used for single sweep operation by disabling the delaying sweep, which is accomplished by complete counter-clockwise rotation of the delaying sweep **STABILITY** control. The main sweep is then reset with the **RESET MAIN SWEEP** key. The **READY** indicator will light, indicating that the main

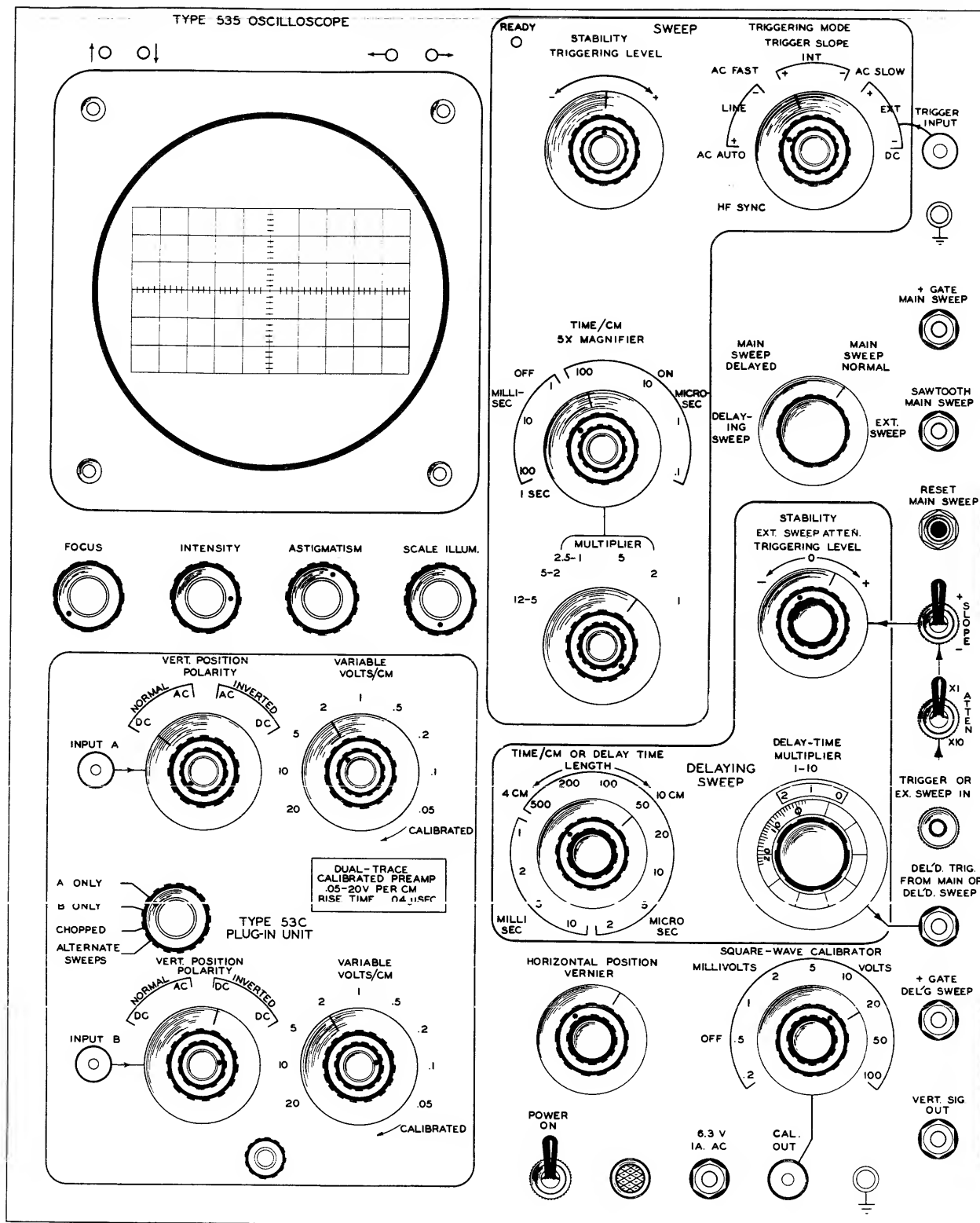


Figure 19. 535 Front Panel





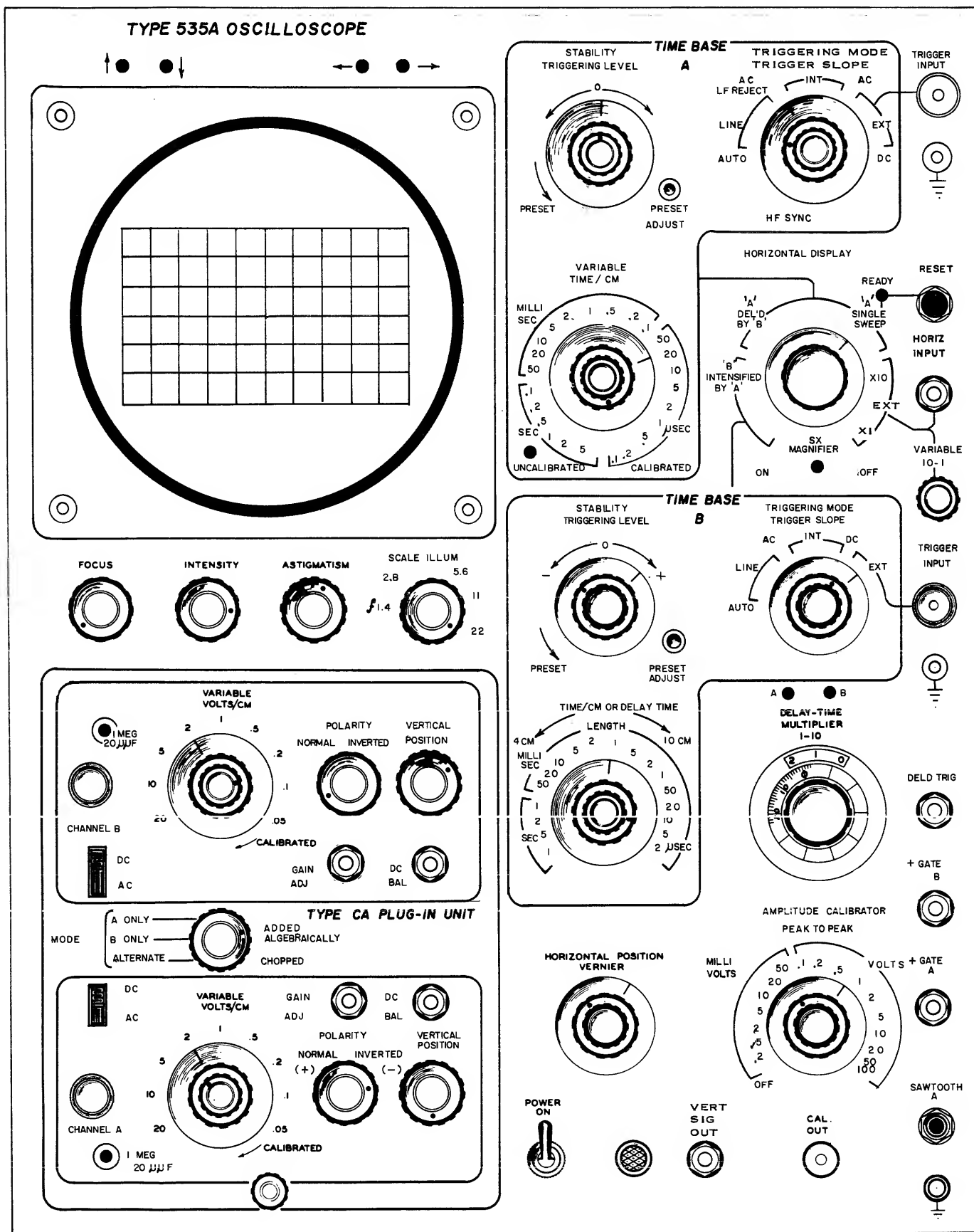


Figure 21. 535A Front Panel

## Control and Jack Changes

**MULTIPLIER.** No MULTIPLIER control is on the 535A/545A.

**TIME/CM AND 5× MAGNIFIER.** This control has been changed to TIME/CM AND VARIABLE. The larger black control is TIME/CM and is a 24-position switch. Positions are from .1 microsecond to 5 seconds. The smaller red control is the VARIABLE. This control provides uncalibrated sweep speeds that are continuously variable between the steps of the larger control. The slowest sweep speed is extended to approximately 12 seconds/centimeter with this control. An indicator, UNCALIBRATED, is lit whenever the VARIABLE control is not fully clockwise. The 535A/545A 5× MAGNIFIER is controlled by a switch mounted concentrically with the HORIZONTAL DISPLAY switch. An indicator is lit whenever the magnifier is on.

**STABILITY AND TRIGGERING LEVEL.** A preset position has been added to both STABILITY controls. The extreme counter-clockwise position (preset) energizes a switch that inserts a screwdriver-adjusted potentiometer in place of the STABILITY control. The screwdriver adjustments are made from the front panel and are labeled PRESET ADJUST. The potentiometers are adjusted to the synced, or triggered, stability setting.

**AMPLITUDE CALIBRATOR.** One control replaces the two controls of the 531. The control is a 19-position switch; one position turns the calibrator off, and the other positions select amplitudes from .2 millivolt to 100 volts in 18 steps.

**TIME/CM OR DELAY TIME.** This switch has 18 positions from 2 microseconds to 1 second on the 535A/545A.

**SLOPE.** This toggle switch is replaced by a dual control, TRIGGERING MODE and TRIGGER SLOPE. The larger black control is the TRIGGER SLOPE switch and is identical to the corresponding time base A control. The smaller red control is a three-position switch selecting one of three triggering modes for time base B. The three modes are DC, AC, and auto.

**HORIZONTAL DISPLAY.** The 535A/545A HORIZONTAL DISPLAY switch has seven positions:

1. Ext. ×1. The input to the horizontal amplifier is connected to the HORIZONTAL INPUT jack.
2. Ext. ×10. An ×10 attenuator reduces the signal applied to the HORIZONTAL INPUT jack before it is fed to the horizontal amplifier. A +100-volt source provides continuous unblanking when either external position is selected.
3. A Single Sweep. This position selects single sweep operation. The RESET key and READY indicator are adjacent to this position of the switch.

4. A. This position provides a normal display using time base A only. This is the same mode as 535 main sweep normal.
5. A Del'd by B. Time base B is used to arm time base A. This is the same mode as 535 main sweep delayed.
6. B Intensified by A. Time base B deflects the beam but both time bases provide unblanking. This is the same mode as 535 delaying sweep.
7. B. Time base B is used to provide a normal display. Time base A is not used in any manner.

A AND B. These two indicator lamps show which time base sawtooth is being fed to the delay pick-off circuit. B should be lit in all positions of the HORIZONTAL DISPLAY except A and A Single Sweep.

## Operating Sweep Delay Oscilloscopes

All information in the 531 Operation Section applies directly to any of the sweep delay instruments, and should be read before operating the 535, 535A, or 545A.

The sweep delay feature is of no use unless the operator knows when and how to use it. Knowing when to use sweep delay is largely a matter of experience; however, the following two points should be remembered.

1. When looking for a particular pulse or waveform and it appears too small to be examined, try sweep delay. Remember that a waveform can be blown up as much as 10,000 times.
2. If an exact time measurement is wanted, use sweep delay.

The sweep delay feature provides greater accuracy than can be obtained with any other display. This becomes increasingly important as the time interval becomes longer.

Obtaining the sweep delay presentation desired depends on knowledge of each control and how it relates to oscilloscope operation. It is also necessary to know the machine being worked with, including the approximate time relations of the waveforms being used. The following suggestions will also assist:

1. Use B intensified by A to determine what is being viewed in A delayed by B. B intensified by A helps to keep the operator oriented.
2. Keep the intensity down in B intensified by A. The brightened portion of the trace cannot be seen if the intensity is too high.
3. Time base B must have a longer duration than time base A. Sweep delay is useless if this is not the case.

4. Do not use the extremes of the DELAY TIME MULTIPLIER. The first and last major divisions of this control are not as accurate as the center divisions. Time base B can be changed to avoid the extremes.
5. Remember that the DELAY TIME MULTIPLIER indicates the number of centimeters to the start (left-most edge) of the main sweep. To determine delay time, multiply the DELAY TIME MULTIPLIER setting by the TIME/CM or DELAY TIME setting.
6. Use A delayed by B (main sweep delayed) for a magnified display and for accurate time measurements.
7. When using long delays, the intensity of an A delayed by B display may be improved by reducing the length of time base B.

Sweep delay oscilloscopes also generate single sweep displays. Use single sweep for special non-repetitive waveforms, such as a damped sine wave. If the STABILITY control is in the free-running position, a sweep will be generated each time the RESET key is depressed. In the synced position, the sweep will not be generated until a trigger is received.

Tektronix oscilloscopes are extremely versatile, and normally provide the desired information in a number of ways. The operator should consider the best display for each situation.

## Plug-In Units for Wide-Band Oscilloscopes

Five plug-in units are available for use in the Tektronix wide-band oscilloscopes. Any of the units may be used with any of the wide-band instruments.

### Model Designation.

The five plug-in units presently supplied for field use are designated B, C, CA, D and G. Older versions of these models may carry a prefix of 53, 54, or 53/54. For example, a type B plug-in may be designated B, 53B, 54B, or 53/54B.

### Type B

Figure 22 shows the front panel of the type B plug-in unit. The unit has provision for two inputs, although only one may be used at any one time. The frequency response is DC to 20 megacycles when the VOLTS/CM setting is .05 or greater. The response for settings below .05 is 5 cycles per second to 12 megacycles.

Type B controls and their functions are:

**INPUT SELECTOR.** This four-position switch selects one of the two input connectors (A or B), and provides AC or DC coupling into the preamplifier.

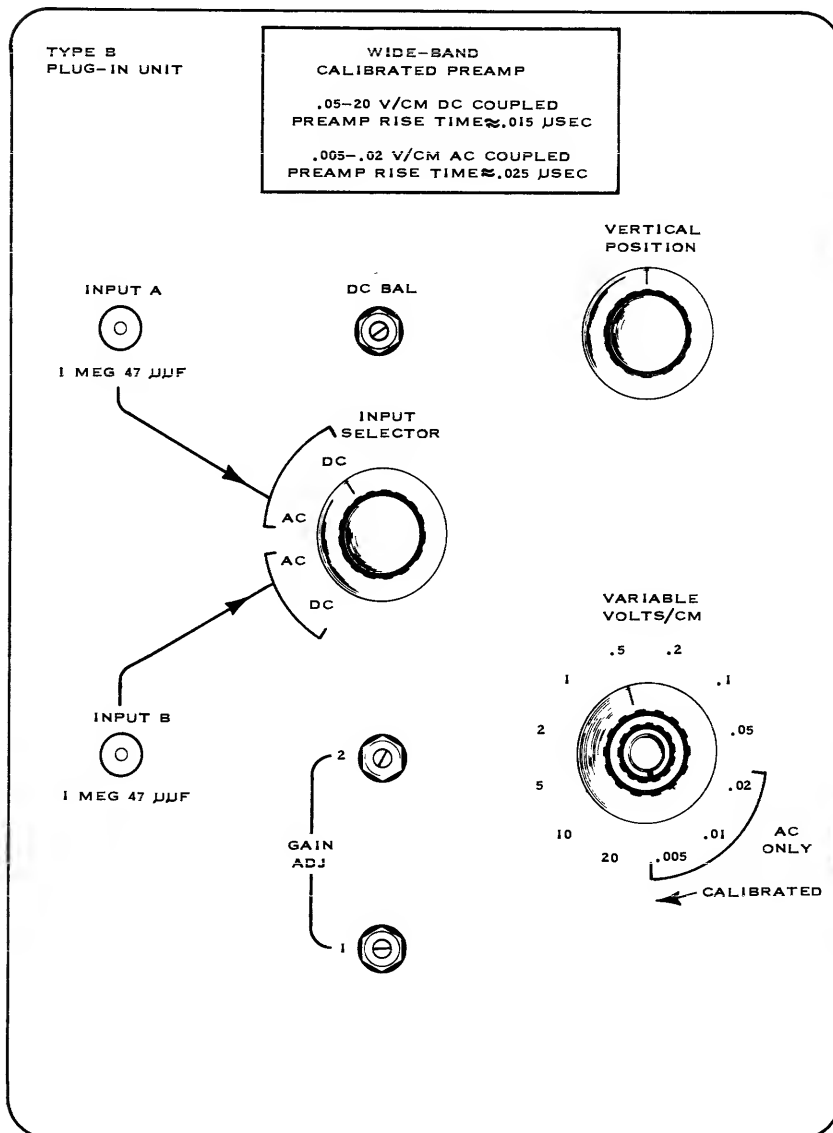


Figure 22. Type B Front Panel

**VERTICAL POSITION.** This potentiometer shifts the trace up or down on the viewing screen.

**VOLTS/CM AND VARIABLE.** This dual control sets the vertical sensitivity. The larger black control is a 12-position switch with positions from .005 to 20. The three lowest positions cannot be used for DC measurements. The input is routed through an additional amplifier stage in these three positions. This amplifier stage is AC coupled and has a gain of 10. The smaller red control (VARIABLE) provides uncalibrated sensitivities between the steps of the larger control.

In addition to the main controls, three screwdriver adjustments are available:

**DC BAL.** This adjustment is made to eliminate vertical trace movement when the VARIABLE control is rotated.

**GAIN ADJ 1.** This potentiometer sets the basic preamplifier gain and must be made prior to GAIN ADJ 2. The potentiometer controls the gain of a preamplifier stage that is used for all positions of the VOLTS/CM control. To make the adjustment:

1. Display a .2 volt waveform from the voltage calibrator.
2. Set the VOLTS/CM control to .05 and VARIABLE clockwise.
3. Set GAIN ADJ 1 for exactly four centimeters of deflection.

**GAIN ADJ 2.** This potentiometer sets the gain of the preamplifier stage used in the .005, .01, and .02 positions of the VOLTS/CM switch. To set this adjustment:

1. Display a 20-millivolt waveform from the voltage calibrator.
2. Set the VOLTS/CM control to .005, and VARIABLE clockwise.
3. Set GAIN ADJ 2 for exactly four centimeters of deflection.

### Type C

Figure 23 shows the front panel of the type C dual-trace unit. This plug-in unit contains two preamplifiers with separate inputs and controls. The controls for each channel are:

**VOLTS/CM AND VARIABLE.** Sensitivities are from .05 to 20 volts/cm in nine steps. The VARIABLE control provides sensitivities between the steps.

**VERTICAL POSITION.** This shifts the trace up or down on the viewing screen.

**POLARITY.** This four-position switch controls the phase and coupling into the preamplifier. AC or DC coupling may be chosen, and the signal may be inverted or left in its normal phase.

**OPERATING MODE.** This switch controls the connection of the outputs of the two preamplifiers to the main vertical amplifier. This switch has four positions:

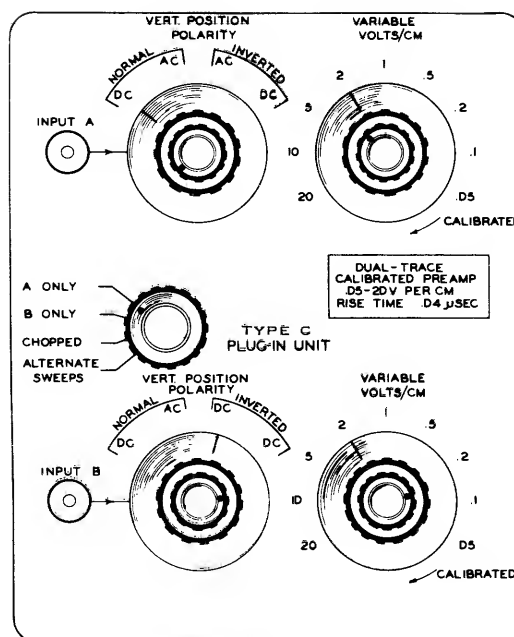


Figure 23. Type C Front Panel

1. A Only. The output of preamplifier A feeds the vertical amplifier of the oscilloscope. Input B is not used.
2. B Only. Only the B input and preamplifier are used.
3. Chopped. A 100 kilocycle switching circuit alternately switches between A and B. In this mode, two traces are seen on the viewing screen. Each trace is composed of small segments of approximately five microseconds duration. This mode should be used only for slow (1 millisecond or longer) waveforms that are not repetitive. Use an external trigger for chopped displays.
4. Alternate Sweeps. A switching circuit changes inputs at the end of each sweep. Thus, the two inputs are displayed on a time-sharing basis. Entire waveforms may be compared with this display.

GAIN ADJ and DC BAL screwdriver adjustments are available for each channel. These adjustments are performed as described for GAIN ADJ 1 and DC BAL of the type B plug-in.

### Type CA

Figure 24 shows the front panel of a type CA plug-in unit. This unit is an improved version of the type C. Although CA controls are arranged differently, they perform the same functions as the controls of the type

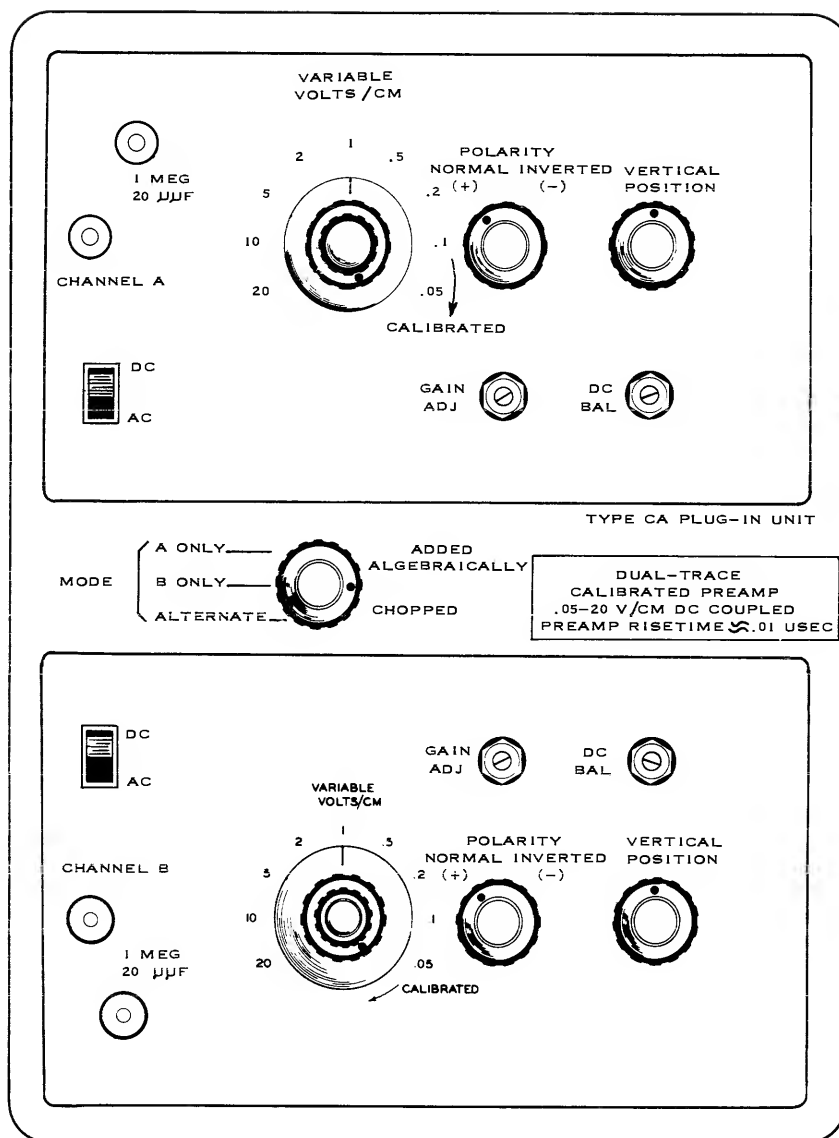


Figure 24. Type CA Front Panel

C unit. The one exception is an additional position of the OPERATING MODE switch. The new position is **ADDED ALGEBRAICALLY**. In this position, in-phase signals will add. For example, if input A and input B are both +20 volts at a particular instant, the resulting display indicates +40 volts on the viewing screen. However, to obtain this result, the **POLARITY** switch of both channels must be set to normal, and the **VOLTS/CM** controls must be at the same position. If one of the **POLARITY** switches is in the inverted position, an effective subtraction results. In the example, if one of the **POLARITY** switches is set to inverted, the resulting display is  $(+20) + (-20)$ , or 0 volts. If both **POLARITY** switches are set to reversed, the display is  $(-20) + (-20)$ , or -40 volts.

Thus, setting one **POLARITY** switch to reversed results in a differential display because out-of-phase signals will add. For example, if input A is +20 volts and input B is -20 volts, the display is  $(+20) + (+20)$  or +40 volts. This is true if B **POLARITY** is inverted. If A **POLARITY** is inverted, the display is  $(-20) + (-20)$  or -40 volts.

### Type D

Figure 25 shows the front panel of the type D, high-gain, differential plug-in unit. In addition to the normal applications for a differential unit, an undesirable signal may be cancelled out because in-phase signals cancel when fed into a differential unit. Cancellations

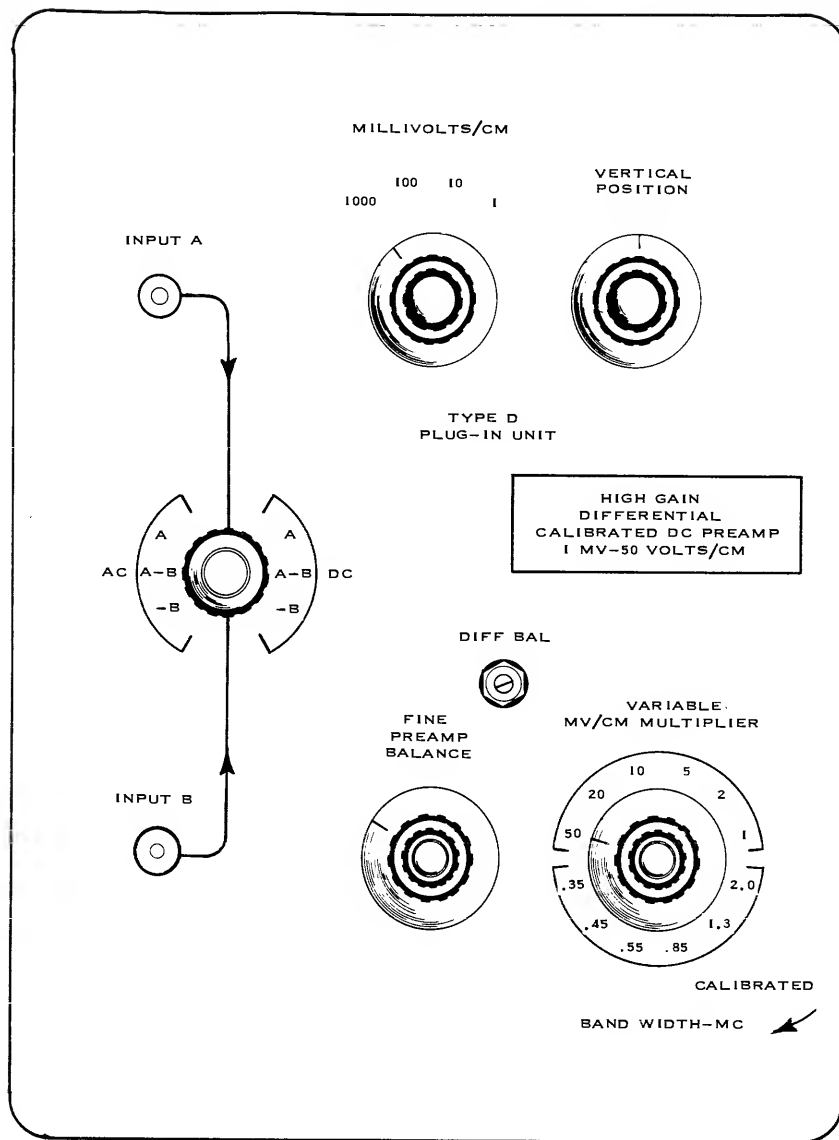


Figure 25. Type D Front Panel

tion is accomplished by feeding a sample of the undesirable signal into one input while the signal to be observed is fed into the other input. By controlling the amplitude of the undesirable signal, it can be cancelled from the display.

Controls of the type D are:

**INPUT SELECTOR.** This six-position switch displays channel A, B, or the difference (A-B). This switch also controls coupling (AC or DC).

**MILLIVOLTS/CM.** This four-position switch controls the basic sensitivity of the unit. Both channels are affected by this switch.

**MV/CM MULTIPLIER AND VARIABLE.** This dual control multiplies settings of the MILLIVOLTS/CM control. The larger black control is a six-position switch providing

steps of multiplication from 1 to 50. This control also indicates the band width of the unit for each setting. The smaller red control provides uncalibrated multiplication factors between the steps of the larger control.

**VERTICAL POSITION.** This shifts the trace up or down on the viewing screen.

**PREAMP BALANCE.** This dual control provides DC balance of the unit. The smaller red control is a vernier for the larger control. The adjustment is made to prevent vertical trace shifting as the VARIABLE control is rotated.

**DIFF BAL.** This screwdriver adjustment provides minimum output when the same signal is fed into both inputs. Make the adjustment as follows:

1. Set INPUT SELECTOR to A-B.

2. Set MILLIVOLTS/CM to 1, MV/CM MULTIPLIER to 5, VARIABLE clockwise.
3. Connect a 20-millivolt signal from CAL OUT to both inputs.
4. Adjust DIFF BAL for a straight line display.

### Type G

Figure 26 shows the front panel of the type G, wide band differential unit. This unit is similar to type D,

but has lower sensitivity and higher bandpass. Separate sensitivity controls (VOLTS/CM) are provided for the two channels. The DC BAL and GAIN ADJ screwdriver adjustments are made in the same manner as the corresponding adjustments for type B. The DIFF BAL adjustment is made as for type D with the following exceptions:

1. Set both VOLTS/CM controls to .05, and VARIABLE clockwise.
2. Use a two-volt signal from the CAL OUT jack.

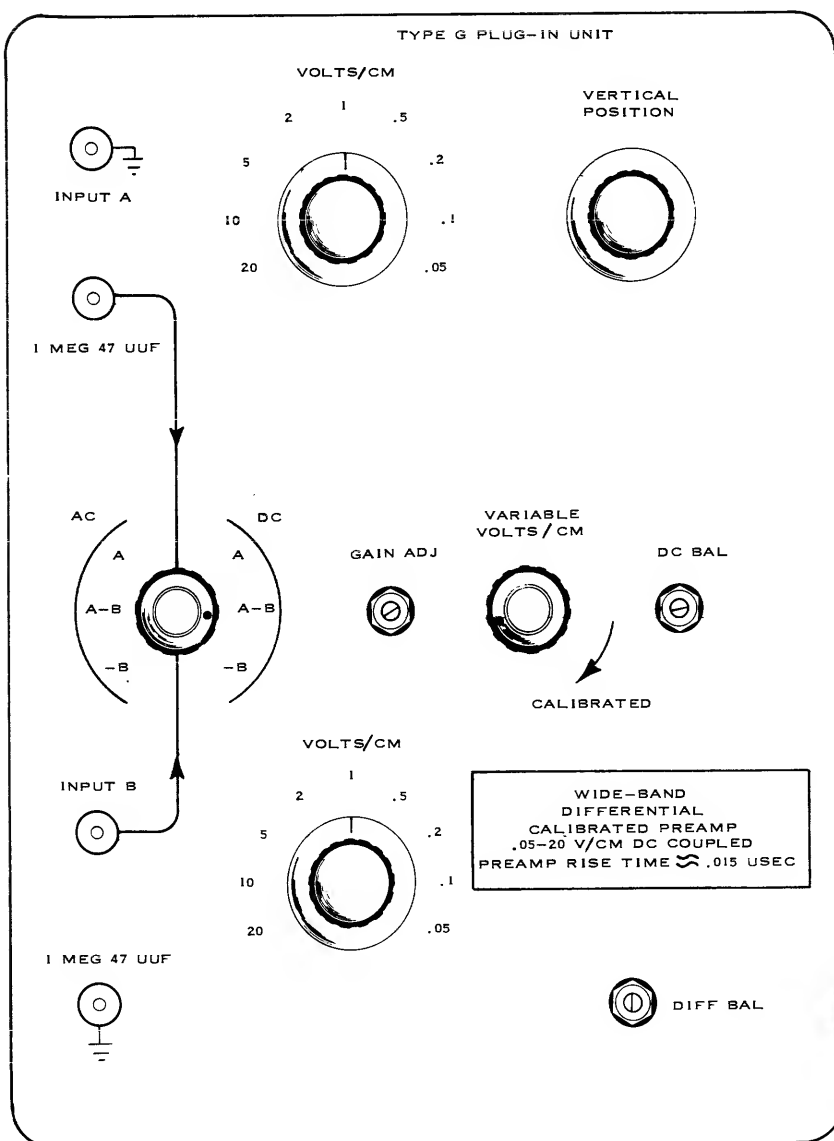


Figure 26. Type G Front Panel